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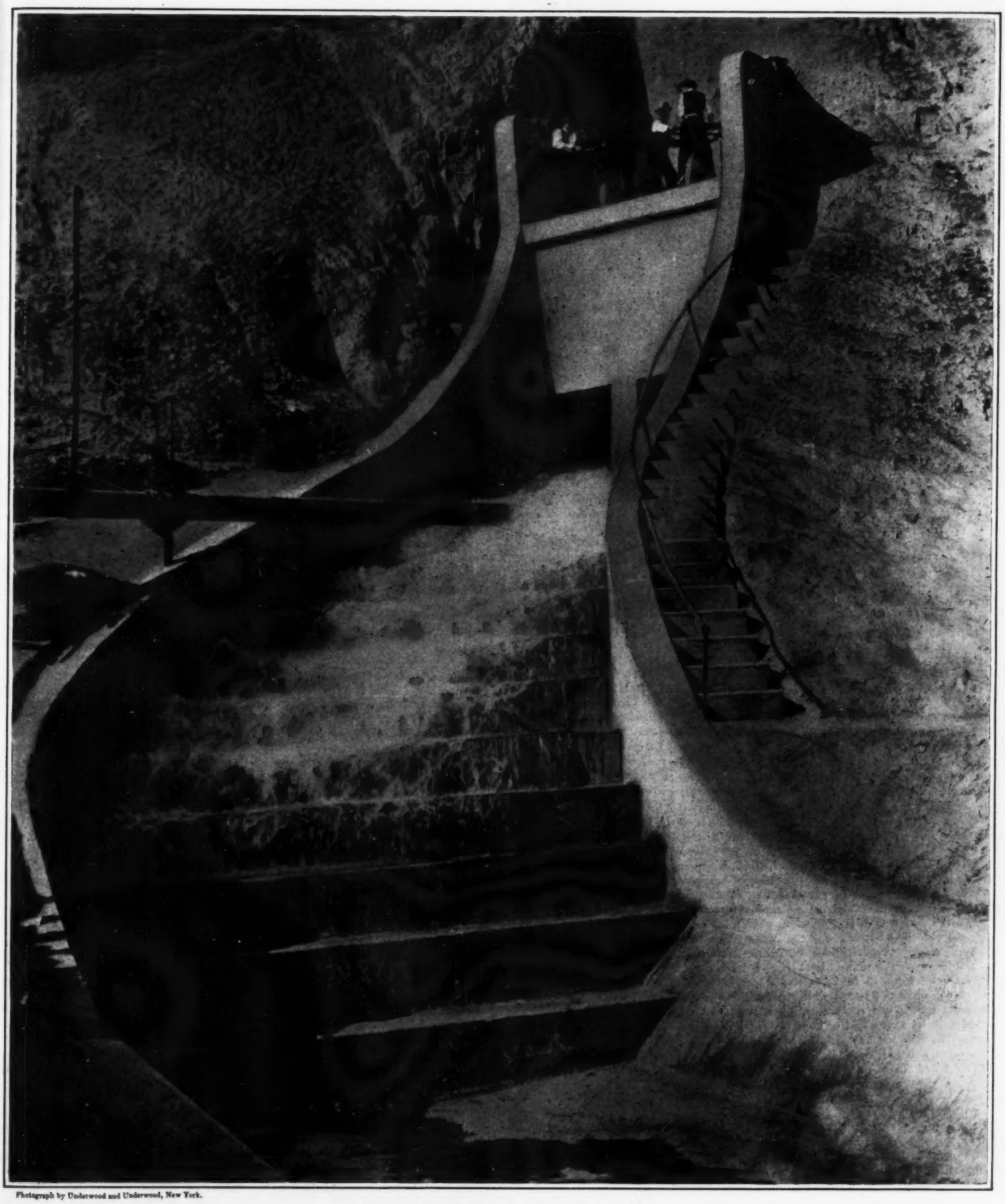

Photograph by Underwood and Underwood, New York.

Opening the flood gates of the Los Angeles aqueduct.

COMPLETION AND DEDICATION OF A TWENTY-SIX MILLION DOLLAR WATER SUPPLY SYSTEM.—[See page 371.]

The Problem of River Crossing in New York City Traffic*

The Tunnel System and the Railway Terminals

By G. F. Kunz, Ph D., D.Sc.

WITHIN the last half-decade, the transportation of passengers to and from the City of New York has entered upon an entirely new phase—one equally remarkable from both an engineering and a practical viewpoint. Although New York is built upon an island, it is possible now to enter or to leave it without the use of ferries, by a system of tunnels beneath both the rivers that confine it. There have been constructed and opened no less than three tunnels under each river, all of them for the passage of railroad trains. Of these six tunnels, five have two tubes and one has four, making fourteen tubes in all. Their dimensions vary widely, as did also the conditions under which they were constructed, owing to differences in the nature of the material penetrated, so that the engineering problems to be met have been highly complicated and varied.

The great example and precedent for a sub-aqueous tunnel has long been the celebrated one beneath the Thames at London. The construction of this tunnel was easy in comparison with those at New York, from the fact that its course lay mostly in a stiff compact clay, which kept its place firmly around the tube and held the tube in position; while at New York there was a great variety of material to be traversed—solid rock, decomposed rock, sand, boulders, mud, and soft river silt—in some places even quicksand. All manner of devices and modifications had to be adopted, to meet these diverse conditions; and it is no small triumph of technical skill that all the obstacles have been overcome and all the tunnels are now in successful operation.

There remains, however, a very important question, which only time can decide, viz., whether the constantly moving loads passing through these tunnels, and the vibration thereby caused, may not after a while produce strains or deflections in the long reaches of the tubes that traverse soft or almost semi-fluid material. Upon this point engineering authorities differ widely in opinion. Thus far, no indication of any such tendency has been detected; but it may yet be too good to regard the problem as permanently solved.

A sub-aqueous tunnel-tube for rail-cars has two distinct functions to perform—not only to provide an elongated chamber for the trains to traverse in safety, as in a land tunnel, but also to support their weight. For the former—to resist the pressure from without—strength of construction is all that is necessary; but if the tube lacks proper support as a whole, no strength of construction can assure its absolute security. The question is as to a tube 1,500 or 2,000 feet long and 15 to 20 feet in diameter—a ratio of 100-1—firmly supported at both ends, but resting on and surrounded by soft or semi-fluid silt for most of its length. So serious did this problem appear to some of the engineers engaged upon the earlier of the New York tunnels that they advocated, and began, a system of supporting pile-work to form a basis for the tube, by which the tube would become simply a water-tight chamber for the cars to pass through. This method was adopted in the first East River tunnel opened—the Subway tube from the Battery to Brooklyn—and was planned also for the Pennsylvania Railroad system under the Hudson. But the first Hudson tube, that known as the Morton Street, or later as the McAdoo tunnel, which was many years in construction, with long intervals of suspended work, showed no trace of anything like displacement under long-continued and most careful tests; and hence the pile-foundation project was given up as unnecessary in the construction of the Pennsylvania tubes.

With various modifications of detail, the general character of all the tunnels is similar—a tube, ranging in diameter from 15 to 23 feet, and consisting of a succession of rings 2½ feet wide of strong iron plating, bolted on from one to another, by flanges, and then lined with some two feet or more of brickwork or concrete. Each track has a tube, and the two may be separated and entirely independent, or may be close together and almost united.

A few words may be given to the East River tunnels, before considering those under the Hudson. There was a small tunnel carried across under the East River some years ago, from about Sixty-ninth Street to Ravenswood, for the Long Island City Gas Company. This, however, was but a small affair, though it was very interesting to students of local geology, as giving the first definite information as to the exact character of the rock underlying the river.

The passenger tunnels beneath the East River are three, as already stated. The first of these, opened in 1907, was the Rapid Transit tunnel from the Battery, New York, to Joralemon Street, Brooklyn, designed to connect the subway systems of the two boroughs. It consists of a pair of tubes 15 feet in diameter within and runs about half way through rock on the Manhattan side—some 2,000 feet—and then through mud, gravel and sand to Brooklyn.

Next above this come the tunnels of the Pennsylvania Railroad Company at Thirty-second and Thirty-third Streets. In view of the great prospective demands of travel between Long Island and the Pennsylvania system of roads it was decided to construct four tubes here, instead of the usual pair. These have an outside diameter of 23 feet—four feet less than the Blackwall (Thames) tunnel—and are in two sets or pairs, some sixty feet apart, those of each set being closely adjacent. On passing out from the rock of Manhattan Island into the soft material of the river channel, quicksand was entered and serious difficulty was found in carrying the shield and machinery along the true line of direction. About half the length of these tubes is in rock, which rises in two ledges (though entirely buried) with deep channels between.

The third set is that known as the Belmont, or New York and Long Island Railroad, tunnel, crossing the river from East Forty-second Street to Long Island City. Here there are two tubes, with a dimeter of 15½ feet. The work at this point was mainly in rock, much of which, however, was decomposed and soft. Advantage was taken of a reef—really a southern extension of Blackwell's Island—to sink a shaft whence boring could be run in both directions, as well as from the two shores, thus giving four headings. Only about one quarter of this tunnel lies in soft river-filling, in the deep channel East of the reef.[1]

This tunnel is intended to connect with the New York Central Railroad System, at the Forty-second Street terminal, as the previous set does with the Pennsylvania station at West Thirty-second Street, both being carried from the river to the terminal by rock-tunnels beneath the city.

The tunnels beneath the Hudson River are also three, one being that of the New York and New Jersey Railroad Company, often called the McAdoo tunnel, from Fifteenth Street, Jersey City, to Morton Street, New York; and the other two, one above this and one below it, both connected with the Pennsylvania Railroad system and leading to and from its up-town and down-town terminals, at Thirty-second Street and Cortlandt Street respectively.

The McAdoo tunnel calls for particular notice, as being not only the first to be opened (February, 1908), but by far the first begun or even attempted. Its inception goes back a full generation—to 1874—when Mr. DeWitt Clinton Haskin, who had been connected with the building of the Union Pacific Railway, undertook the project of carrying a tunnel beneath the Hudson. A working shaft was sunk, a little back from the foot of Fifteenth Street, Jersey City, and another near the foot of Morton Street, New York—somewhat over a mile apart—5,400 feet. The shaft was a circular pit 30 feet in diameter and 65 feet deep, enlarged into a chamber at base, whence the parallel tubes of the tunnel were started on a gentle grade. Little was then known as to the nature of the material filling the river-bed, and the shield-method was employed; it was thought that the material could be excavated by hand-labor, and would retain its position, with the aid of compressed air, while the steadily advancing tube could be lined with thin iron plates and then with brickwork 2½ feet thick laid in hydraulic cement. The work progressed slowly for several years, until in July, 1880, a terrible accident occurred. The overlying silt at the point then reached was only a few feet thick, and unable to withstand the force of the compressed air; the result was a "blow-out," followed by an inrush of water, which disarranged the air-lock and cost the lives of twenty laborers. The work was resumed, however, and went on for two years, when it was suspended from lack of funds, after about 2,000 feet of the north tube had been constructed.

Eight years then passed, until the enterprise was taken up by an English company in 1890, with Sir John Fowler and Sir Benjamin Baker of the Forth bridge as consulting engineers. The shield system was now introduced, and progress was much more rapid. But in 1891 the work was again abandoned, after 2 000 feet more had been traversed, in less than two years—as much as in the eight years at first.

The tunnel then lay abandoned for several years, in which time it filled with water, while public interest in the attempt had completely died out. It is greatly to the credit of Mr. W. G. McAdoo, that he saw the possibility of once more taking up this work, already two thirds completed, although twice given up, and of not only finishing the tunnel itself but developing it on a much more important scale.

Mr. McAdoo undertook this great task in 1896; a new and strong company was formed, known as the Hudson and Manhattan Company, and Mr. Charles M. Jacobs was placed in charge as chief engineer. The old tunnel was pumped out, and found to be mostly in good condition. It was kept in order and carefully watched until 1902, when work was actually resumed. The shield used by the English company was readjusted and used for the north tunnel; and a new shield was built and equipped with new machinery for the south tube. A novel and peculiar difficulty was now encountered in the form of a ledge of rock on the New York side which rose only partially above the floor of the tunnel, thus necessitating simultaneous excavation in rock below and in silt above. Special additions and modifications had to be devised, to meet this new obstacle; but it was successfully overcome and the whole work accomplished without accident, to the great credit of Mr. Jacobs. The unfinished portion of the north tube (1,400 feet) and the greater part of the south tube were completed in about five years, and formally opened on February 25, 1908.

Unlike the other tunnels, the two tubes of this one differ somewhat in size; the northern one having a diameter of 19 feet 5 inches outside and 18 feet 1 inch within, while the southern tube is smaller, being 16 feet 7 inches without and 15 feet 3 inches within. This difference is due to the fact of their being constructed, as above stated, by different companies, a number of years apart.

The tunnel thus described, however, is but a small part of the work—only that beneath the river. It is extended much farther, under the cities on both sides of the Hudson, to form very important railroad connections. In New York it is carried as a rock tunnel for over half a mile, to Sixth Avenue and Ninth Street, and there it divides into two branches, one going across to Fourth avenue, to connect with the Rapid Transit Subway, and the other continuing under Sixth Avenue to Nineteenth Street, and ultimately to connect with the main Pennsylvania Railroad Station at Thirty-second Street. On the New Jersey side a tunnel has been built parallel to the river, to connect all the railroad terminals on that side with each other and with New York. This system consists of two tubes of 15 feet internal diameter, and extends from the D. L. & W. terminal in Hoboken southward to the Pennsylvania Railroad station in Jersey City, taking in the Erie Railroad between, and is to go on to that of the New Jersey Central Railroad below. At Fifteenth Street this tunnel (or subway) meets and joins the river tunnel, with its New York connections. This junction is itself a most remarkable piece of engineering work; it consists of three immense caissons, or subterranean chambers, made of reinforced concrete, 45 feet wide and high and 106 feet long, the largest ever constructed. In these, the tubes of both tunnel systems are made to connect in a most ingenious manner without any crossing of tracks by a two-story construction of each caisson.

But this remarkable achievement did not exhaust the energy and foresight of Mr. McAdoo. He perceived the importance of a tunnel that should meet the needs of the great downtown district of New York; and hence the Hudson and Manhattan Company undertook the construction of another pair of tubes, a mile or more south of the old tunnel, to connect the Pennsylvania Railroad station in Jersey City directly with the great new Terminal building in Manhattan, at Cortlandt and Dey Streets. This is the second Hudson tunnel, opened on July 19, 1909. It consists of two tubes of larger size, 23 feet in external diameter, and not running side by side, as in the other. From Jersey City they diverge slightly, the southern one being used for trains to New York, and going under Cortlandt Street into a station excavated beneath the great Pennsylvania downtown terminal. There the track turns northward, and then, curving to the west, under Fulton Street, returns through the other tube to Jersey City. The length is a little over a mile.

* Reprinted from Appendix B of the Eighteenth Annual Report of the American Science and Historic Preservation Society.

[1] As to the general characteristics of the East River bottom, see Charles P. Berkey, "Geological Features Affecting the Plan of Construction of the City Tunnel of the Catskill Aqueduct," New York, 1912, pp. 144, 166-168, Report of the Board of Water Supply . . . on the City Tunnel.

The stations at both ends of this tunnel are again very notable structures—great subterranean chambers, excavated in rock to a depth of 80 or more feet, and lined with concrete—one beneath the Pennsylvania terminal in Jersey City and the other beneath that in New York. The former also connects directly with the subway already described, beneath Washington Street in Jersey City, and the latter with the Rapid Transit Subway at Cortlandt Street, New York. All the great lines of passenger travel, therefore, both local and distant, are linked together in this remarkable manner.

The third tunnel under the Hudson, opened in 1910, was constructed by the Pennsylvania Railroad Company to bring its whole body of passenger trains directly into the great station recently erected in West Thirty-third Street, and to connect with the Long Island extensions.

The change of policy on the part of the Pennsylvania Railroad from a bridge to a tunnel was brought about by an investigation and computation made by the late J. J. Cassatt. On his return from Europe in 1900, he said in regard to the bridge projected from Hoboken to Twenty-third Street, New York, which had been planned by Lindenthal, that as it would cost at least $200,000,000 it would be impossible to entertain the proposition and that the subject of tunnels must be investigated.

The Pennsylvania Railroad Tunnel consists of two tubes having an outside diameter of 23 feet, but running side-by-side. Their actual under-water length is about three quarters of a mile, but their extensions and approaches are very much longer. The tubes have, of course, the usual iron casing, but of extra strength, and are lined with two feet of concrete. On each side of the track, moreover, the concrete is carried up vertically to a level with the car-windows, where it then forms a horizontal platform extending to the wall on either side, wide enough for a person to walk upon and affording a means of exit for passengers in case of accident or breakdown. The original plan was to sink a series of piles—cast-iron tubes 2 feet 3 inches in diameter and 1½ inches thick—to a bed-rock, as a foundation for the tunnel. These were to sustain the weight of the heavy trains, which it was thought might cause strain or deflection in the tubes. This feature was given up, however, in view of the perfect stability shown by the other Hudson tunnels, after some months of operation. Had this been undertaken it would have proved a Herculean task, and probably an impossible one. The same difficulty that has already been emphasized as to piers for bridges would have been speedily encountered. The contractors would have found themselves engaged in attempting to sink piles from one to two hundred feet, and then to unknown depths before rock could be reached. How far, indeed, the present stability of the unsupported tunnels may prove permanent, is a question of possible concern, though we must hope that it may never become actual. The much vaunted "mastery of man over nature," however, has limits.

On the New Jersey side, which the tunnel reaches at a point some three-quarters of a mile south of the D. L. & W. terminal at Weehawken, connection is made with the subway, running parallel to the river already described. The tunnel itself, however, is continued in a straight line northwestwardly, for a mile or more, under the Bergen Ridge, the southern extension of the Palisades. On emerging from the portal on the farther side of this ridge the tracks are carried west upon an elevated embankment, over the meadows and the Hackensack River, as far as Harrison, N. J.—nearly to Newark—where they join the main line of the Pennsylvania road. Here the electric traction used in the tunnel system is exchanged for steam; and there are also great yards for the distribution of freight, etc.

At the New York entrance, or "portal," at Thirty-third Street and Tenth Avenue, the two tracks pass into a system of switches, and increase in number until they become twenty-one in the great Seventh Avenue Station. Here begins then the eastward extension—the tracks being reduced to four, which are carried in a rock-tunnel across the city to First Avenue, where they enter the four-tube tunnel under the East River, previously described, leading to Long Island City. The total distance between the end or "portal" of the tunnel here, and the Bergen portal beyond the Hudson, is 5.3 miles—crossing under both rivers and the whole breadth of Manhattan Island between them.

Here again are immense yards, and two most important connections. One of these is the branch of the Pennsylvania Railroad extending north to Port Morris, and passing over Hell Gate by the magnificent arch bridge previously described. This will give short and direct rail connection with the whole New Haven system, and thus between all New England and the South and West. The other is the Long Island Railroad, with its network of branches, now affiliated with the Pennsylvania road. This will not only place the great suburban population of the island, present and prospective, in direct touch with the Pennsylvania system, but may acquire extreme importance in another way entirely. If the project recently suggested, although still in the future—of making a port for the mammoth Atlantic liners at or near Montauk Point—shall ever be carried out, the Long Island Railroad would become the carrier of most of the passenger traffic to and from Europe. The question of piers at New York long enough for the giant steamers even now building, is already assuming a serious aspect, and the Montauk proposal may well develop into a reality ere many years. If it should, this connection would become of national, or even international importance.

Such is the tunnel system of New York city—unique in its extent and in its variety, in its engineering difficulties and triumphs, and in its practical relations to the conditions and needs of the metropolis of the Western World. This paper is concerned mainly with the subriver tunnels, especially those beneath the Hudson, but these have to be considered in their relations to the whole system, of which they form an integral and most remarkable part. The problem of crossing the Hudson, impracticable in respect to bridges, from the geological conditions of the channel, has been solved by means of tunnels, apparently with complete success.

From the foregoing account of the system of tunnels thus far developed under the Hudson and East Rivers, it will be seen that all of them are, as already stated, made and used for railroad service alone. All are constructed on the same plan—that of a tube containing a single track; and with no provision or space for any other use, save the limited footpath in the Pennsylvania tunnels for exit in case of accident. The great volume of travel and traffic that does not or cannot use the railroads, must still cross the Hudson by ferry alone. This state of things cannot continue long, now that railroad tunnels have been successfully constructed, and the method is shown to be so feasible. In a later issue we will review briefly some of the schemes proposed for traffic tunnels under the rivers, and also for subway routes to connect them with each other and with the principal thoroughfares.

The Los Angeles Aqueduct

Dedication and Opening of the Great Water Supply System

In the issue of November 8th, 1913, of the Scientific American there appeared a detailed illustrated account of the new Los Angeles Aqueduct, which is designed to bring 265 million gallons of water daily over a distance of 234 miles from the Sierras to Los Angeles.

This new aqueduct was dedicated and opened to use on November 5th, and on our front page of this week's issue we present a view taken at the moment when the gates were opened to start the flow of water down the cascade formed below the exit of the tunnel through the Santa Susana Range. This cascade fulfils a double function—it was designed partly on esthetic grounds, but also for the purpose of assisting in the purification of the water by aeration, i.e., oxidation of impurities contained therein. This exit from the tunnel is situated 25 miles northwest of the city of Los Angeles, the tunnel itself being 1,600 feet long. The cascade covers a drop of 167 feet.

The date for the dedication had originally been set for June 18th, 1913, but a failure of the Sand Cañon Siphon, 175 miles north of Los Angeles, caused delay by necessitating the construction of a new siphon. The reconstructed siphon is built of 2,552 feet of pipe measuring from 8 to 10 feet in diameter. The entire work was completed within 123 days after the destruction of the original line. This represents a record in work of this character, a record made under most exacting conditions, the temperature reaching at times as much as 124 deg. Fahr. The new siphon was tested on September 19–23, with complete success. Incidentally, the first 68 miles of the aqueduct have been in operation since February 12th, and the Haiwee Reservoir has been in the process of filling.

"On September 27th, at 7:30 P. M.", says B. A. Heinly, in the *Engineering News*, "the water of the Owens River reached the Fairmont Reservoir, a regulating basin of 7,620 acre-feet capacity governing the flow through the five-mile Elizabeth tunnel, situated on the northern edge of the Coast Range, 198 miles from the intake and 35 miles from the outlet of the aqueduct. Three days were required for the filling of this reservoir to a point where the water level was at an elevation sufficient for maintaining a flow through the Elizabeth tunnel. On the morning of October 1st, Mayor H. H. Rose, in the presence of a number of aqueduct engineers and various other city officials, turned the lever which lifted the gates sufficiently to permit of a passage of 15 seconds-feet. After passing out of the southern portal of the tunnel (as the penstock of power house No. 1 and about 2,000 feet of power-pressure tunnel are not completed), the water by a temporary diversion was turned into the natural channel of the San Franciscquito Cañon. Seven miles below it was again diverted into the aqueduct, and on October 2nd the filling of the Dry Cañon Reservoir, a power-regulating basin of 1,325 acre-feet, was begun. The flow was then gradually increased to 80 seconds-feet. October 14th, the water of Owens River entered upon the last 12 miles of its journey to the outlet of the system. This section of the aqueduct has been in operation for the past year and a half, a small pumping plant pumping from wells into the Soledad Cañon Siphon, the water then being taken out at the outlet of the aqueduct through a 14-inch sheet-steel pipe and carried three miles to the San Fernando Dam, where it was used for sluicing purposes. On the morning of October 16th, the outlet gates were opened and a flow of 15,000 miners' inches was permitted to play for several hours over the cascade referred to above. Thus was completed the initial operation of the great water supply system.

"In addition to these tests, nature herself severely tested the work during September. In this month the Southwest was visited by a severe and unusual heat wave which in the mountain region facing on the desert was accompanied by cloudbursts of unprecedented violence. One of these occurred in the Tehachapi Mountains, where in Tehachapi Pass it carried out the main line of the Southern Pacific Railroad for four or five miles. Continuing on down, heavily laden with débris, the avalanche of water reached a covered conduit section of the aqueduct and piled it high with sand and boulders. In one place the cover was broken for a distance of several hundred feet, but at all other points the work well showed the character of the materials and of the craftsmanship.

"While the actual capacity of the aqueduct is still to be determined by calibration of all the various sections, the studies that have so far been made go far to prove that the estimate of a net delivery of 20,000 miners' inches was too conservative on the one hand and that the allowance of 1,550 miners' inches for seepage losses was too extensive on the other. It is confidently expected that final measurements will show an actual delivery capacity approaching 25,000 miners' inches, with the city's water holdings in the Owens Valley capable of delivering this amount."

The Dörwald Heat Engine

It is claimed for the Dörwald engine that it is an entirely new type of internal combustion engine working on a gradual combustion principle. The combustion is insured by means of super-compressed air which is raised in pressure by a pump moving transversely within the bucket-type piston and actuated by a prolongation of the connecting rod beyond the gudgeon pin. A fuel pump, also placed transversely in the piston, is driven by a projection from the connecting rod placed below the gudgeon pin. These connections impart the maximum motion to the pumps when the engine is passing the dead centers. The cylinders communicate with a crank chamber and have inlet and outlet ports arranged relatively to each other in the usual manner. Above the piston and communicating with the air pump chamber is a space in which vaporization takes place, and a sparking plug is provided for starting the engine. Depending from the piston and opening into the oil-pump chamber are two tubes which telescope into the jet-tubes of two float chambers attached to the crank chamber and from which the supply of oil is taken as the piston moves to and from the bottom of its stroke, one jet being in action when the engine is running in one direction and the other when it is reversed.

The arrangement of the valves is such that after the piston has effected the main compression the air supercompressed by the small transverse pump flows into the space above the piston, raising the pressure and temperature still higher. Simultaneously the oil pump begins to discharge the oil into the highly heated space and this discharge continues for about four tenths of the stroke. As the oil does not begin to enter the cylinder until just after the piston has begun the outward stroke there is no danger of pre-ignition. The gradual combustion of the oil by maintaining a more even pressure keeps down the cylinder stresses and the weights of the various parts. There are few working parts in the engine and an entire absence of cams, levers, eccentrics, and valve rods. Each cylinder is a separate unit and in a multiple-cylinder engine any cylinder may be thrown out of action if required.—*London Times.*

A Recently Installed Fatigue Testing Machine*

Description of Machine and Records of Some Tests

Prof. G. B. Upton

WHICH hurts an automobile more, one 500 mile race, or two 250 mile races, with rest spell between? Is metal like muscle, that it can recover from fatigue? What is the effect of rapidity of time of cycle loading and unloading, with the same maximum stress limits, on the number of applications of load before "fatigue" break? What heat treatment is best, and what worst, for an

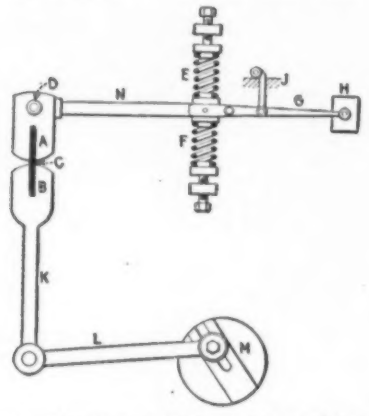

Fig. 1.—Diagram of Upton-Lewis machine for fatigue tests.

automobile axle? Questions such as these are now puzzling engineers. The study of "fatigue" failure and its conditions has recently become of great importance in experimental engineering, for the development of the automobile has suddenly uncovered the extent of our ignorance in this field.

Sibley College has installed, and used in class work during the past term, a new type of fatigue testing machine, the invention of Prof. G. B. Upton of Sibley and Prof. G. W. Lewis of Swarthmore College. The machine is intended to do rapid and approximate, but relatively accurate, testing in two lines of usefulness, the study of heat treatment of steel as affecting strength and toughness, and the study of resistance to "fatigue."

The scheme and actual construction of the machine are shown in Figs. 1 and 2. The jaws *A* and *B* (Fig. 1) securely clamp the specimen, which is rectangular in section, ¼x¾ inch, or ¼x1 inch, and about 6 inches long. The jaw *A* swings on a hinge pin at *D*; *B* is fastened to *A* through the test piece, but only while the machine is running. Stops are provided so that the jaw *B* will not fall far when the test piece breaks.

The free length of the test piece between the jaws is fixed at the same value for all tests. In the work reported here the free length was either 1/10 inch or ¼ inch. The jaw *B* carries the arm *K*, which is oscillated by the connecting rod *L* and variable-throw crank wheel *M*. The jaw *A* carries the arm *N*, held at its farther end between the springs *E* and *F*. These springs can be set under any initial tension desired; it is essential that at maximum throw neither spring comes loose from *N*.

The motion of *N* in the spring is magnified by the pencil arm *G*, hinged on the link *J*, and recorded on paper on the drum *H*. The paper drum is driven by a 300: 1 reducing motion from the crankshaft. A flywheel on the crankshaft carries the machine over the points of maximum throw. The machine can be cranked by hand through a reducing gear if desired. Under power the speeds can be varied in four steps from 100 to 500 revolutions per minute.

The pencil records are of the form shown in Fig. 3, which represents the record of one of the short runs. In general the height *y* (the pencil travel) represents the strength of the metal while the length of the record shows its ductility or toughness.

PRELIMINARY TESTS IN DEVELOPMENT OF MACHINE.

A series of preliminary tests were made to establish relations between the crank throw and number of cycles

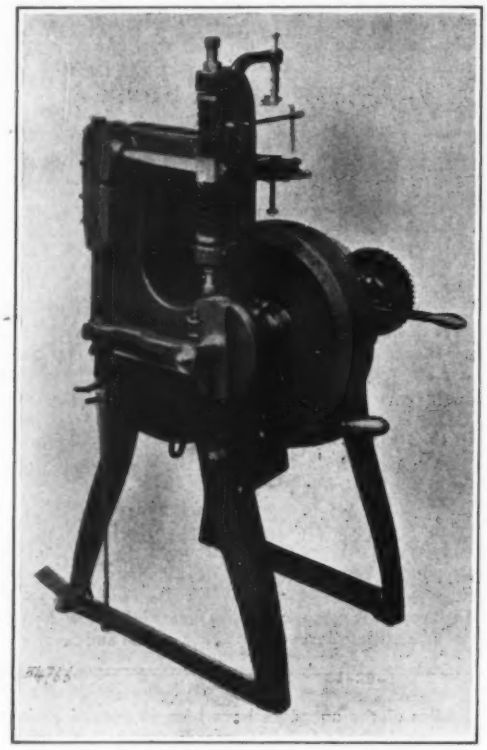

Fig. 2.—Upton-Lewis fatigue testing machine.

required to break the specimen, net angle of bond and number of cycles; crank throw and pencil motion, and stress and number of cycles. In these tests records were kept of: kind of material; crank throw; pencil motion; value of *n*, the number of cycles or revolutions of the crankshaft by the automatic counter; dimensions of section of the piece; revolutions per minute of the machine and notes on the behavior of the machine or piece.

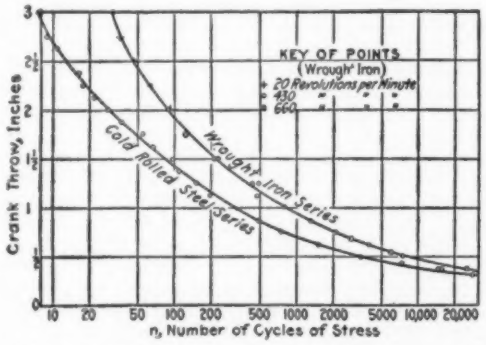

Fig. 4.—Relation of crank throw and number of cycles to break specimen.

To work up the data the springs were calibrated, and all dimensions of the machine taken. From the spring strengths, the lever arm, section of dimensions of the piece, and measurements of *y*, the pencil travel, the nominal maximum stress of the transverse loading cycle was computed at $\frac{10720y}{bt^2}$ where *b* and *t* are the breadth

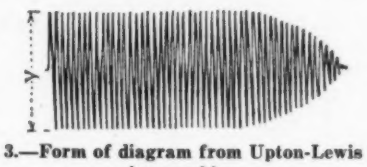

Fig. 3.—Form of diagram from Upton-Lewis testing machine.

and thickness of the test-piece section. With $b = 0.750$ inch, $t = 0.250$ inch, this reduces to

$$p_{max} = 229{,}000\ y.$$

From the lever arms, crank throw *x* and pencil motion *y*, the angle of bend of the piece at each loading was in radians $L = 0.1502x - 0.0171y$, in degrees $L = 9.12x - 0.981y$. This angle is the total angle through which the piece was bent back and forth in each cycle, the angle between the extreme positions. This bend was made to occur on a free length of the piece of 0.1 inch. The maximum value of this angle was about 26 deg. +; 13 deg. + on each side of the straight piece.

The consistency of operation of the machine may be judged from Fig. 4, where the crank throw in a series of tests is plotted against the number of cycles to break (the latter being plotted on a logarithmic scaling), and from Fig. 5, where net angle of bend, in degrees, is plotted against the number of cycles. In Fig. 5 both ordinate and abscissa have logarithmic scaling. It will be seen that the points fall regularly on the curves with an accuracy fully up to that required in good engineering or scientific testing.

In Fig. 4 the curves were drawn as single, and had to be forced and flattened in the region around $n = 100$. In Fig. 5 it is apparent that the curves should be two-branched, splitting at about $n = 100$. The only difference between the ordinates of the two figures is a slight correction to the angle of bend imposed by the crank throw, due to the yielding of the springs as recorded by the pencil.

The pencil throws were intended to give the stresses. It was found that the crude pencil motion used in the preliminary machine was likely to become loose and wobbly at times, and again, when tightened, stiffened to have too much friction. It is obvious from the curves of Figs. 4 and 5 that the stresses were, and the pencil motion should have been, smoothly variable with the crank throw. Therefore, curves were drawn of the pencil motion versus the crank throw, and the varied values of the pencil motion taken from these curves were the values used in computing the stresses given in the tables. With computed stresses the curves of Fig. 6 were plotted, stresses versus the number of cycles, both ordinate and abscissa being logarithmically scaled.

It is most interesting, in such a series of tests, to watch the change in appearance of the fracture with the number of cycles to break. A piece of ductile material broken with from one to ten applications of load (bending) breaks as in tension test, with a fracture of the cup and cone type, shear at 45 deg. outside and tension, square across the piece, in the middle.

This shearing at 45 deg. inward from the outer surfaces disappears at somewhere between 10 and 100 applications of load, the exact number depending upon the material. Beyond 100 applications the breaks are square. This change in form of break occurs at the branching

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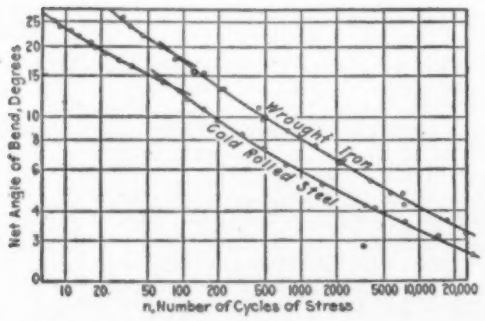


Fig. 5.—Relation of net angle of bend and number of cycles to break specimen.

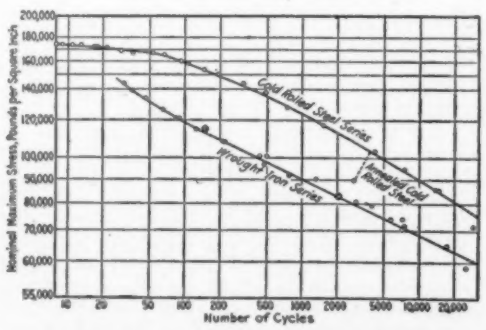

Nominal Maximum Stress, Pounds per Square Inch
Cold Rolled Steel Series
Wrought Iron Series
Annealed Cold Rolled Steel
Number of Cycles

Fig. 6.—Relation of stress and number of cycles.

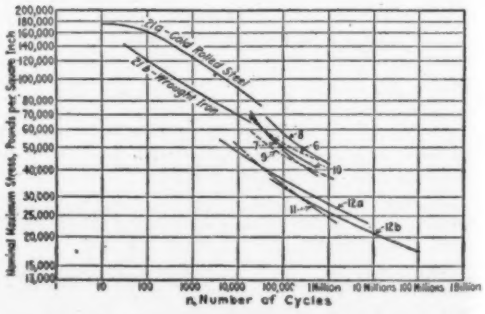


Fig. 7.—Relation of stress and number of cycles—grouping of results.

point of the curves in Fig. 5. Between 100 and 5,000 applications the semi-fibrous appearance of the fracture changes to a dull, smooth appearance, except in the case of bad material. At 5,000 cycles and beyond, the fracture truly presents the actual crystal and grain size of the material to the eye or the microscope.

A good material run with 5,000 or more applications to break should show a dull grayish surface on a square break (perhaps irregularly square), with a grain size too small for the naked eye to make out. The nearest approach to the appearance in things familiar to the engineer is the break of a good, properly refined tool steel.

To show the relation of the preliminary tests on the Upton-Lewis machine to other fatigue tests, Fig. 7 was plotted. In this, curves 21*a* and 21*b* are the Upton-Lewis curves. Curves 6, 7, 8, 9, 10 and 11 are from tests by Eden, Rose, and Cunningham; 6, 8 and 9 on mild steels, 7 and 10 on wrought irons, and 11 on copper. Curves 12*a* and 12*b* are from Wohler's work on wrought irons. Together the curves cover the range from break in 10 applications of load to 100,000,000. Some facts of the highest importance are apparent from inspection of this group of curves. For any single material the curve of nominal stress vs. number of cycles is continuous, not two or more branched, from around 100 cycles to break up the highest numbers. For similar materials these "endurance curves" are substantially parallel to each other throughout their length when plotted as log (stress) vs. log (number of cycles). Endurance curves for non-similar materials have different slopes, as shown by 11, copper, in contrast to 12*a* and 12*d*, wrought irons.

These facts lead to certain conclusions of great significance in the attempt to standardize fatigue testing for commercial purposes. Since endurance curves of similar materials are substantially parallel, tests of relative endurance can be made just as well at high stresses as at low stresses. This allows a great shortening of the time required for testing, a shortening which is necessary if fatigue testing is to become at all generally used commercially. In every case a number of test pieces of the materials to be compared should be run at various initial stresses, so as to plot for each a short portion of the endurance curves. Testing all pieces at the same stress has already proved unsatisfactory in commercial practice. The comparison of corresponding portions of the endurance curves is found to be necessary.

Vanadium Steel Main and Side Rods*

Three Years' Service Records

SERVICE records of the Michigan Central Railroad show that, through the use of vanadium steel for main and side rods, failures of these parts have been reduced 80 per cent.

This represents a comparison between the percentage of failures of vanadium rods on Consolidation and Pacific type engines built since 1910, since when rods of this material have been practically standard on this road for these types of engines, with the percentages of failures of carbon steel rods, on the same classes of engines built since 1906, taking into consideration in the latter case only those failures which occurred within a period of three years' service or less. The comparison includes 90 locomotives equipped with vanadium steel main and side rods and 84 equipped with carbon steel rods. In other words, it is a comparison of failures of carbon and vanadium steel rods on a practically equal number of locomotives during the same length of service. Locomotives which have gone into service since the first of this year have been omitted, as, naturally, no failures would be expected during such a short period of service.

The records show that to date there have been only 3 failures of vanadium steel rods, a ratio of six tenths of one per cent. All of these failures were of side rods. On the other hand, the failures of carbon steel rods prior to 1910 that failed within a period of service of 3 years amounted to 3⅓ per cent.

Furthermore, it is shown by the records that on one lot of engines built in 1907 equipped with carbon steel rods, the failures of side rods during 3 years' service amounted to 10 per cent.

Of the above engines equipped with vanadium steel rods, two thirds have been in service since 1910.

The three failures were confined to the first rods applied. These were among the original applications of vanadium steel locomotive rods; and at that time the heat-treating equipment of the locomotive builders might be said to have been temporary and was not comparable to their present facilities. Also when vanadium steel rods were first introduced, the locomotive builders' practice was to simply anneal them. Later the double heat-treatment now followed was adopted.

One of the above 3 failures of the vanadium rods occurred through the knuckle pin hole and the other two near the end.

Of the failures of carbon steel main and side rods, 50 per cent occurred in the body of the rod and the other half either through the crank pin or knuckle pin holes.

The average length of service of the broken carbon steel rods was less than 2½ years.

Further analysis shows that whereas none of the vanadium steel main rods have failed since 1910 to date, the percentage of failures of carbon steel main rods on the above types of engines during an equal length of service amounted to 2.4 per cent, taking into consideration all Pacific and Consolidation type locomotives installed since 1906, and including only those failures which occurred within a 3-year period of service.

Lake Shore and Michigan Southern Railway service records, including the Lake Erie and Western and Chicago, Indiana and Southern, show that since 1910, when vanadium rods became practically standard for road engines on these roads also, the failures of the vanadium rods have amounted to only 1.3 per cent. Thorough comparison with failures of carbon steel rods on these roads is impossible, as prior to 1910 complete records of rod failures were not kept. The only basis of comparison is limited to a few road engines built in 1910 equipped with carbon steel rods. On these engines, the failures of side rods to date have amounted to 6 per cent. On this basis, the comparison shows a reduction of 78 per cent in rod failures in favor of vanadium steel.

On the New York Central and Hudson River Railroad, records show that the failures of vanadium steel rods since 1910 amounted to six tenths of one per cent.

Summarizing the records on the above five roads; out of a total of 757 road engines equipped with vanadium steel rods, installed since 1910, the total number of rod failures to date have amounted to only three fourths of one per cent.

Because of the successful results from vanadium steel rods on those roads which were pioneers in their use, rods of this material have been specified by 20 roads on locomotives ordered this year.

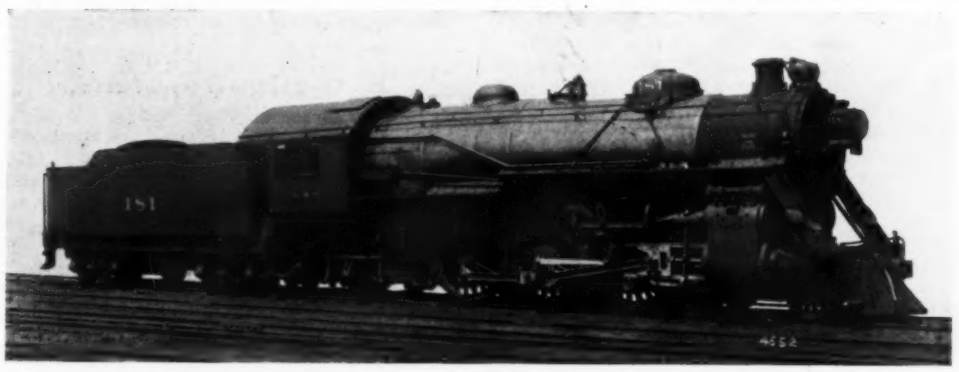
At the present time there are over 1,400 locomotives equipped with vanadium steel rods, either in service or under construction, on over 30 railroads.

Locomotive rods are subjected to complicated stresses, which it is difficult, and it might be said, practically impossible to accurately calculate. This is probably more true of rods than any other parts of the locomotive, with the possible exception of frames.

A high factor of safety is essential to provide against failures. Considerations not only of maintenance costs, but also of safety, demand the greatest care in design and selection of material to reduce the possibilities of failures to a minimum.

Because of their higher physical properties, heat treated vanadium steel rods offer additional strength and increased insurance against failure.

* Reproduced from *American Vanadium Facts*.



141-Ton Pacific locomotive—Chesapeake & Ohio Railway, equipped with vanadium steel frames, rods and main rod straps

POWERFUL PACIFICS FOR THE C. AND O. EQUIPPED WITH VANADIUM STEEL FRAMES AND RODS.

For handling difficult passenger service on the Allegheny district of the Hinton division between Clifton Forge and Hinton, W. Va., the Chesapeake and Ohio ordered early in the year eight powerful Pacific type locomotives. These engines have recently been delivered and because of their capacity, design and the difficult service conditions under which they are to operate are of especial interest.

Vanadium steel was first used on the Chesapeake and Ohio for the above parts in 1910, when it was specified on a 2662 type Mallet engine ordered from the American Locomotive Company, which marked the introduction of this type on the C. & O. R. R.

Since that time, vanadium steel frames have been specified for practically all heavy road power on this road, and during the past two years this material has been used for rods also.

Including the engines here under discussion, a partial list of the equipment built within the past three years for the Chesapeake and Ohio and associated lines, equipped with vanadium steel frames, include the following locomotives, and of these approximately 50 are equipped with vanadium steel rods: 62 Mallets with a total weight of 425,000 pounds; 61 Mikados weighing 323,000 pounds; 3 mountain type locomotives weighing 330,000 pounds; 8 Pacific type locomotives weighing 221,000 pounds; 31 consolidations and these new Pacifics of 282,000 pounds total weight.

On the above division, where these new engines will operate, the ruling grade eastbound is 30 feet to the mile. Westbound there is a 13½-mile grade of 60 feet to the mile.

These Pacifics are designed to haul a train of ten cars, weighing 692 tons, over the division without assistance, maintaining an average speed of 24 miles an hour over the 60 feet grade. Double heading has been necessary heretofore, when handling trains of this weight with Pacific type locomotives.

They have a theoretical maximum tractive effort of 44,000 pounds. With 179,000 pounds on drivers, the ratio of adhesion is 4.08. Making the usual allowance for the superheater, the equivalent total heating surface is 5,105 square feet, or 276 square feet per cubic foot of cylinder volume. These ratios indicate that the weight on driving wheels is fully utilized for tractive power purposes and that the steaming capacity is ample for severe duty.

Preliminary trials in service indicate that they will be fully capable of meeting the service requirements. They are representative of the exceptional capacity that can be obtained in the Pacific type when track conditions permit high wheel loads to be carried.

The vanadium steel main frames are braced just ahead of the leading driving pedestals, by a large steel casting, which in addition to acting as a cross-tie, supports the driving brake shaft. The valve motion bearer braces the upper frame rails between the first and second pair of drivers. Between the second and third pairs this function is performed by a broad steel casting.

At the splice between the main and rear frame sections is a large transverse brace. Transverse braces are also applied at the main driving pedestals.

Among the other interesting features of the design are: Main driving boxes of the Cole pattern, with journals 11½ x 22 inches; an installation of 460 Tate flexible stays in this make of boiler; a brick arch; Schmidt superheater and a pneumatically operated grate shaker.

The general dimensions of the design are as follows:

Weight in working order, total	282,000 pounds
Weight on drivers	179,900 pounds
Weight on leading truck	51,300 pounds
Weight on trailing truck	50,800 pounds
Weight of tender	161,000 pounds
Wheel base, driving	13 feet
Wheel base, total	34 feet 1 inch
Wheel base, engine and tender	67 feet 11½ inches
Cylinders, diameter and stroke	27 x 28 inches
Driving wheels, diameter outside	73 inches
Boiler, working pressure	185 pounds
Firebox, length and width	114 x 75¼ inches
Tubes, number and outside diameter	206 x 2¼ inches
Flues, number and outside diameter	36 x 5½ inches
Tubes and flues, length	20 feet 6 inches
Heating surface, tubes	3,535 square feet
Heating surface, firebox	220 square feet
Heating surface, arch tubes	31 square feet
Heating surface, total	3,786 square feet
Superheater heating surface	879 square feet
Grate area	59.6 square feet
Tender, water capacity	8,000 gallons
Coal capacity	14 tons

What Are the Ten Greatest Inventions of the Age, and Why?

Scientific American Prize Contest; Essay Which Received Honorable Mention

By "Kennebec" (L. P. Webert, Bath, Maine)

In the following paragraphs are briefly described ten inventions which the writer has chosen as the ten greatest inventions of the last twenty-five years because their application has and will benefit more people than any other inventions developed during the last twenty-five years.

THE ELECTRIC FURNACE.

The electric furnace furnishes a splendid means of producing a high grade steel economically. A great demand for better rails and structural material has been created during the last few years. Poor rails are the cause of a great number of accidents.

The electric furnace of to-day embodies the same principle as is found in the electric arc lamp invented a hundred years ago. When an electric current is passed between two pieces of carbon, an intense heat is evolved at the point where they touch, producing light. In Fig. 1 we have a sketch of a Girod electric furnace for the refining of steel. Current passes between the electrode *a* and the molten metal. The metal is in electrical connection with iron terminals *b*, of which there are six in all, though only two appear in the section shown. An arc is produced between the electrode *a* and the molten steel. This arc heats the metal and keeps it in a fluid condition. The impurities (phosphorus and sulphur) in the steel are gradually absorbed by the slag which covers the metal. There are other types of electric furnaces such as the Stassano where the heat of a number of arcs is radiated down upon the charge. The Heroult furnace which embodies the same principle as the Girod furnace in Fig. 1 is a furnace which has become popular in steel refining. The Rochling-Rödenhauser furnace belongs to the induction type of furnaces. An alternating current is passed around two iron cores passing up through this furnace, which arrangement does not come in contact with the iron to be refined. The metal takes the form of a figure eight about these cores. When the current passes, it induces a current in the metal, which produces the heat necessary. We also have the Acheson type of furnace in which a current is passed through a resistor of carbon which becomes the heating element. The electric furnace gives us steel, calcium carbide, carborundum and other products of great value.

THE INCANDESCENT LAMP.

The incandescent lamp is a modern necessity. No other form of illumination can equal in variety of applications our present electric lamp. Thomas A. Edison gave us the carbon filament lamp. He could not stop with that invention. He was compelled to devise new electrical machinery and apparatus to accompany his lamp. His carbon filament lamp is now passing out of existence. Its place is being taken by the tungsten filament lamp. Tungsten is a metal having a very high melting point, about 3,000 deg. Fahr. Less than ten years ago it was universally conceded to be a very brittle metal. In recent years the laboratories of the General Electric Company have produced this metal in ductile form of an exceedingly high tensile strength and have drawn it out into fine wire, in which form we find it in our present lamps. Tungsten lamps consume about one third the quantity of current used by the carbon filament lamp and give a better quality of light.

THE MOVING PICTURE.

Thomas A. Edison has given us the moving picture. This is a great invention because the moving picture business being carried on on such a gigantic scale, can furnish not only a cheap but also a very instructive form of entertainment. In the manufacture of the moving picture a sensitive photographic film is exposed rapidly to the scene to be reproduced in the moving picture. This film is then developed like an ordinary photographic film on a large drum which revolves in the photographer's developer and solutions. When developed and fixed a positive is made on another film of the same size in the same manner as the finished print is made in ordinary photography. When the film is completed it is sent to the moving picture shows and is there passed before a powerful electric arc light at the same speed as the original film was exposed to the object. Sometimes the film is passed faster. Beyond a certain speed the eye can not detect the rapid passage of each picture exposed to view on the screen. As a result we see the objects and people move on the screen.

THE PHONOGRAPH.

Another invention Thomas A. Edison has perfected is the phonograph. We do not appreciate this invention as much as we did when it was introduced years ago. People tire of it especially when the neighbors use it Nevertheless we can preserve for posterity the voices of our great singers. When the phonograph becomes developed to the same degree as the moving picture has been developed, and can be used in connection with it, which eventually will come to pass, we shall have a combination that will furnish the highest

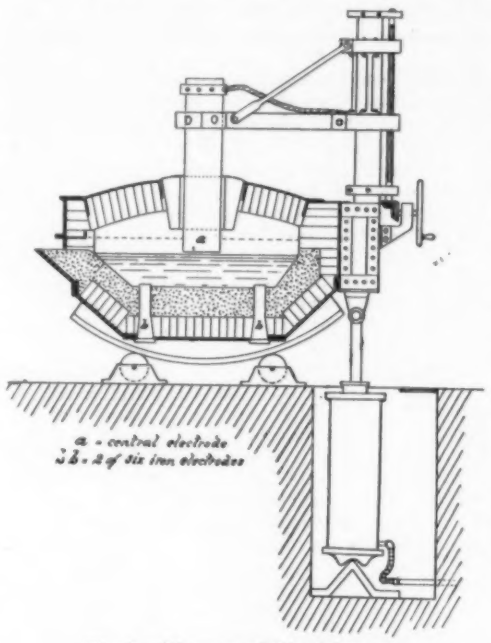


Fig. 1.—Diagram of Girod furnace.

type of amusement. This invention can be described as follows: A needle which is attached to a small diaphragm travels along on a grooved wax cylinder or disk. The human voice striking the diaphragm actuates it and the needle attached, the latter producing impressions on the wax as it travels in the groove. When the needle passes over the impressions in the wax the same sounds are reproduced. After the record, as it

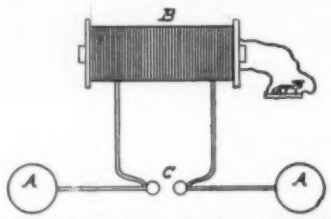


Fig. 2.—Diagram of wireless transmitter.

is termed, is completed, copies are made of it in wax or hard rubber and placed on the market.

WIRELESS TELEGRAPHY.

In 1899 Guglielmo Marconi established a wireless system of telegraphy between England and France. During the last two years the importance of this invention as a means of communication to ocean traffic has been fully appreciated. Every large vessel carries a wireless apparatus. When wireless telegraphy becomes perfected it will perhaps mean more to the world

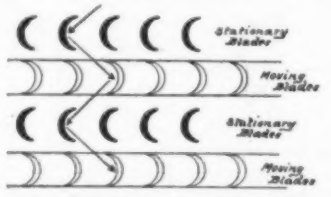


Fig. 3.—Diagram of turbine blades.

than the cable and telegraph do at the present time. Wireless telegraphy can be explained briefly as follows: We have an induction coil *B* (Fig. 2) consisting of a primary coil connected to a device for rapidly interrupting an electric current sent through it. Another winding of finer wire is wound over the primary winding and is connected to the spheres *AA'*. This coil is known as the secondary coil. The current is rapidly interrupted in the primary coil which produces by induction an electrical charge of great intensity in the secondary winding and also in the spheres *AA'* which are connected to two brass rods separated at *C*. When the charge attains a certain intensity a spark jumps across the gap *C*. This spark creates a path for the charges of electricity on *A* and *A'* which are opposite in nature to come together and neutralize each other. In doing so a series of rapid oscillations is set up which diminish in intensity as the energy stored up in *A* and *A'* is used up. It was discovered that when these oscillations are produced, sparks can be taken from any piece of metal in the neighborhood of the machine. The rapid oscillations give rise to electric waves which are transmitted through space. It is customary to transmit these waves through space by means of wires strung between the masts of a ship. These wires are connected to the secondary coil near the gap *C*. These waves are collected by another set of wires which are connected to a coherer which is a tube filled with silver filings. Under the influence of the waves these filings adhere together and create a path for a battery current to pass. This current actuates a telegraph instrument and responds to the telegraph key at the sending station.

RADIUM.

In 1898 M. and Mme. Curie found in a mineral known as pitchblende a substance emitting powerful radiations, which they called radium. The new element was very difficult to isolate. It accompanies and is associated with the element barium in the various chemical reactions that barium undergoes. When barium is precipitated from a solution as the sulphate or is precipitated as the chloride in a strong alcohol solution, the radium compound is precipitated with the barium. It was finally discovered that when only part of the barium chloride is separated in the alcohol solution, and this portion dissolved and again partly precipitated in a like manner, the radium becomes concentrated in the last separations. This process, known as fractional precipitation, is carried on until a product very rich in radium is obtained. There are plants built for the separation of radium from the ore. Tons of ore are put through processes and separations to obtain just a few grains of the radium compound.

The chief interest which is attached to this new element is connected with the strange property which it possesses of emitting powerful radiations. These radiations are capable of passing through metals, acting on a photographic plate, and most mysterious yet, are capable of producing a temporary radio-activity in the surrounding substances. Radium is becoming serviceable in the medical world and will find other remarkable applications when it becomes more abundant.

LUTHER BURBANK.

Luther Burbank we can credit with giving mankind a means of "making two blades of grass grow where one blade grew before." Luther Burbank has given us new fruits, roses, grains, grasses and thornless cacti. The Carnegie Institute allows him an annual appropriation of ten thousand dollars to carry on his experimental work at Santa Rosa, Cal. One of his methods consists in sowing seed from one species of plant. When these plants mature, the most vigorous plants, or the plants that approach the ultimate type of plant sought, are selected from, say, a thousand plants of the species. Seed from these plants selected is collected to be sown the following season. The best plants from this lot are chosen to bear to seed. The seed is again sown and plants raised and selected until the desired kind of plant is obtained. Then again the pollen of flowers is transferred from one kind of flower to another to produce certain results. Grafting of different trees and plants gives different varieties. There are doubtless methods made use of which the world knows nothing of, but we know from the results that Mr. Burbank is conferring a great service upon humanity.

THE AEROPLANE.

The Wright brothers of Dayton, Ohio, became entitled to the honor of giving us a flying machine that could be easily and successfully utilized. The Wright aeroplane, the design of which is familiar, consists of two horizontal planes of peculiar design placed one above the other. In the central part of the rear is placed a light, powerful gasoline engine which, being connected to a propeller, drives the machine through the air. The planes being inclined at an angle, receive the pressure of the air on the lower side. The machine is thereby caused to rise. Steering devices are attached to guide the machine up or down, to right or to left. When the Wright aeroplane was introduced other

machines made their appearance. Besides the Wright machine we have the monoplane, the Blériot type and the Curtiss type of aeroplane.

The introduction of the aeroplane is recent. It takes years for any invention to mature and confer a commercial blessing upon the people. Since the aeroplane is now practical we can class it as one of the great ten inventions.

THE DIESEL OIL ENGINE.

One fact in connection with the success of the aeroplane must not be overlooked. Its success depended upon the development of an engine which combined minimum weight with great power. Not until the motor became perfected did the aeroplane become a possibility.

The gasoline engine has attained a remarkable degree of perfection, but when we consider that its use is dependent upon the light volatile petroleum products such as gasoline, benzene, naphtha, etc., the supply of which will rapidly become limited, we note that its present application will not continue very long. The Diesel oil engine is an internal combustion engine that can run on heavy oils, the supply of which is abundant, as they can be obtained not only from natural sources but also as by-products of the distillation of coal and wood. In the early nineties Rudolf Diesel of Munich, Germany, developed the engine which bears his name and he has found it to be the most economical engine yet devised. This engine works in a different manner from the ordinary explosive type of engine. Air is first drawn into the cylinder by the piston. On the return stroke this air is compressed to a pressure of from 450 to 500 pounds per square inch. The temperature of this air during compression becomes sufficiently high to ignite the oil sprayed into it at the end of the stroke. In order to spray in this oil, the oil must be forced into the cylinder under a pressure of 700 to 800 pounds per square inch. All of the oil is not injected at once, but is sprayed in as the cylinder moves forward, the amount sprayed in being in proportion to the amount of work required for that stroke. During the last stroke of the piston the burnt gases are expelled from the cylinder. It is only during the last four years that this engine has been successfully constructed in the United States, owing to the mechanical difficulties encountered. A steady advance of the Diesel engine as a prime mover is noted in the propulsion of sea-going vessels, a number of which have already crossed the Atlantic. When a more conservative use of the nation's fuel supply is insisted upon, this engine will become popular in this country.

THE PARSONS STEAM TURBINE.

Fig. 3 illustrates the principle of the steam turbine. A series of moving blades (the blades drawn light) are mounted on a cylinder called a rotor. These blades move past a series of stationary blades which are mounted on the cylinder casing which surrounds the rotor. The arrows show the direction the steam is compelled to take. In one type of turbine the velocity of the steam strikes the moving blades with a velocity somewhat more than double the velocity of the blades. This is known as the impulse type of turbine. In another type known as the reaction type, the velocity of the steam is about the same as the velocity of the blades. The expansion of the steam between the blades produces the force which turns the rotor.

Charles A. Parsons of England was the pioneer in establishing a practical turbine which made its appearance in the early nineties. His invention can be classed as a great invention for the following reasons:

It occupies less space than any other prime mover of equal power; it cuts down power plant repairs, and requires less labor. A steam turbine's efficiency remains permanent. A steam engine's efficiency deteriorates in service. The superior economy of the turbine, not only in the consumption of steam but in first cost and attendance, is practically eliminating the slow-moving reciprocating engine as a prime mover.

A Human Being Without Cerebral Hemispheres*

THE classic experiment of Goltz in which he removed both cerebral hemispheres from a full-grown dog which was subsequently kept alive for some years has since been duplicated by others and has furnished the basis for important deductions regarding the functions of the portions of the brain involved. In a decerebrate dog it is evident that all those reactions in which the associative memory plays a part are permanently lacking, while the simple reactions that depend on inherited conditions only, may remain. In accordance with this the dog without cerebral hemispheres sleeps and wakes; it moves spontaneously; there is an extreme restlessness doubtless connected with the removal of cerebral inhibitions. Discrimination is shown by such animals with respect to food of varying taste. Goltz's dog could still bark and howl. It could be awakened by noise and it responded to bright light. On the other hand, it could not seek its food and recognized neither master nor companions.

The general impression which one gathers from the investigations of cerebral functions in animals is that their subcerebral centers are complete enough to be able to carry out many motor reactions independently of the higher hemispheres of the brain. It is, of course, desirable to ascertain to what extent the facts of animal experimentation find their analogy in the workings of the human brain. Accidents have furnished numerous instances of partial loss of cerebral substance; but such cases are far from comparable with those in which there is extensive or complete removal of the hemispheres. There are instances on record of human beings born without a cerebrum, but they have been anencephalous fetuses which have survived for only a few days. Even the scanty observations made in such cases have demonstrated that in the absence of a cerebrum movements of the limbs and eyelids, sucking movements and the act of crying can be carried on successfully. It has remained for Edinger and Fischer to furnish the first description of a human being devoid of cerebral hemispheres who has remained alive for any considerable period. Their subject was under observation until its fourth year, when death, due to pulmonary tuberculosis, occurred. We are told that, although the symptoms exhibited by the child gave occasion to assume the existence of some severe brain involvement, prior to the necropsy, no one would have suspected the complete absence of the cerebrum. Entirely occupying the place of this portion of the brain was found a membranous bag filled with fluid, while the lower portions of the central nervous system exhibited a fairly complete and normal structure.

The very satisfactory account of this child's experiences during the three and three quarter years of its life which Edinger and Fischer have fortunately succeeded in obtaining impresses one with the decided inferiority of the decerebrate human subject as contrasted with comparable dogs. The child showed scarcely any change of behavior from its birth to its death. This is not true with regard to decerebrated dogs for which suitable records have been obtained. These learned to walk, to perform simple acts of life, to alternate sleep and waking. The child never acquired such faculties. It lay motionless in sleep unless wakened, and unlike the dogs, failed to learn to take food otherwise than by the primitive act of sucking. Like the dogs, it was apparently blind. It seemed impossible to discover a reaction whereby any relation which was semi-psychic or conscious on the part of the child could be entered into. To quote the German observers: The child without cerebrum was less capable than a decerebrate fish or frog.

The difference in the reactions of various animals to lesions of the motor cortex is now explained by physiologists as being connected with the gradual shifting of functions from the sphere of necessary reactions to the sphere of educatable adaptations, that is, from the lower centers to the cerebral cortex. This is characteristic of the evolution of the higher type of nervous system and is a concomitant of the increased adaptability which distinguishes man from all the lower animals. In the animal without hemispheres the motor mechanisms for all the movements of the body are present and can be set into action from any point on the sensory surface of the body. The first effect of adding the cerebral hemispheres to this mechanism is to increase the range of reactions, to modify or inhibit them, by diverting the stream of nervous impulses into channels which have to a large extent been laid down in the cortex by the past experience of the individual. In the dog, although a portion of the brain is in direct connection with the spinal motor centers, and can therefore initiate movements without making use of the midbrain motor machinery, these movements play only a small part in the motor life of the animal, and the removal of the corresponding centers takes away little of the conscious functions of the animal. In man the enormous power of acquisition of new movements is, as Starling emphasizes further, rendered possible by the shifting of one motor function after another to the sphere of influence of the cerebral hemispheres. Almost every act of human life has come to involve the co-operation of the cerebral cortex. The motor defects and the lack of adaptations exemplified in the child we have described would seem to show that the subcerebral centers in man are not complete and that this lack is permanent.

* Reproduced from the *Journal* of the American Medical Association.

Lubricating Engines in Cold Weather

J. C. HAWKINS writing to *Power* says:

"In a manufacturing plant in a northern State there were two large engines in mills, located some distance apart, which were so exposed that during cold weather it was almost impossible to get the oil to run through a 3-8-inch pipe to the engine bearings. The oiling system is of the gravity type with a tank located about 15 feet above the engine. The engines were about 900 horsepower each, and as there was much dust in the air a copious supply of oil was required to lubricate them. Sometimes the oil would congeal and stop running, and before it could be started again a bearing would start to heat. Each cylinder was supplied with a 4-quart sight-feed oil pump, one of which was of such construction that a U-shaped piece of pipe was placed inside of it with the threaded ends extending through the top. One of the ends was connected to a ¼-inch steam line, and the other to a drip line. This kept the cylinder oil warm so that the pump would work in any kind of weather. The other lubricator had a glass body, and was of such construction that it was not possible to put a heating coil inside of it. But a coil was made by winding a length of ¼-inch pipe around a block of wood having a diameter of 2 inches larger than the diameter of the oil pump. There were about five full turns in the coil which was connected to the steam line and also to a drip line. As this lubricator was more exposed than the other one, a box was made that would just slip over it and the coil to prevent radiation of the heat. That settled the cylinder-oil trouble, but then came the trouble with the engine oil. Each engine had an oil filter in which there was a steam coil in the bottom. Then a coil of ½-inch pipe was made and placed in the overhead tank to keep the oil supply in a fluid state, but in passing through the long, small pipe to the engine it would get thick, and to prevent this a 3-8-inch steam pipe was laid alongside of and fastened to the oil pipe and covered with a 1-inch sectional pipe covering. This kept the oil warm as far as the oil cups, which were all taken off except those on the crank pins, these being taken apart and the body discarded, the pipe being connected directly to the bottom part containing the sight-feed. A ¼-inch valve was put in each line just above the sight-feed. On the crankpin the centrifugal oiler with its cup and stand was retained, the oil pipe being tapped into the top cover, and a steam coil made to fit around the cup. The reason for this was to give a small reserve supply in case the oil in the pipes got too thick to run. Sometimes cylinder oil had to be used to keep the pin cool, which was done by shutting off the engine oil and putting cylinder oil in the cup. A steam and oil line was also run to the outboard bearing. Drip valves were placed on the ends of all branch steam lines, and a steam valve at the connection with the steam pipe. Both engines were piped up in about the same manner, each engine had an engineer who stopped and started, and did his own oiling when he had time, but before the system was changed it took two or three helpers to keep the oil warm.

"After passing over the bearings the oil was collected in a tank below the engine-room floor and pumped by hand to the filter. After passing through the filter it was pumped into the overhead storage tank and used over again. There were two gallons of new oil put into the system every day, and as much was drawn out for lubricating machinery. The oil filter was cleaned monthly.

"This system could have been connected to the exhaust pipe, and the oil heated by waste steam."

Commenting upon this the Editor of *Power* remarks:

"Lubricating troubles of this kind are not uncommon in the North. When the weather is warm is the time to take steps to rearrange the system so that there will be no trouble and fussing about oil lines.

"It is altogether too common practice to locate a gravity oil tank and filters on the engine-room wall or in some other place that is warm in summer but so cold in winter that the oil congeals so before reaching the engines that the supply at the bearings becomes inadequate.

"Pumps or air tanks for elevating the oil are used with most gravity-oiling systems. It should, therefore, be possible in nearly every Northern plant to locate the gravity tanks over the boilers where it is usually quite warm. By putting the oil filters, receivers and pumps in an exhaust-steam heated room beneath the engine-room floor, the entire system could be kept warm. If some of the piping between the gravity tank and the engines is exposed to drafts, as is sometimes the case, besides covering the pipe, a small bypass line might be led around into the receivers. This would create a sufficient circulation of the oil to keep the system warm."

Manual Training for College Professors

TWENTY-EIGHT of the professors in the electrical engineering departments of twenty-six colleges have just had a vacation term of duty as regular employees on the shop pay-roll of the Westinghouse Electric Company at Pittsburgh. Working side by side with the mechanics of the company they, governed by the shop hours and other regulations and receiving the pay of second year apprentices, sought to acquire the shop craft and manual skill that can only be secured by actual shop work.

Fig. 1.—Lemur. Fig. 2.—Howler monkey. Fig. 3.—Proboscis monkey. Fig. 4.—Chimpanzee with exceptional pit.

Figs. 1—4 form an extremely heterogeneous group selected from among monkeys and lemur.

Fig. 5.—Wolf. Fig. 6.—Leopard. Fig. 7.—Chacma baboon. Fig. 8.—Anubis baboon.

Figs. 5—8 show the marked contrast on the inner side of the jaw between the dog-like apes and the Canidae and Felidae.

The Story of the Chin*

When Was the Faculty of Speech Developed in Man?

By Louis Robinson, M.D.

With Illustrations by Mènie Gowland

The human lower jawbone differs in a very essential manner from those found among the rest of the Primates, and all other vertebrates, in having its lower anterior border bent downward and forward so as to form a chin. Recent discoveries of the remains of early men, such as the Heidelberg and Piltdown jaws, have informed us that this distinctive shape of the inferior maxilla has increased in a marked degree since the lower stages of man's existence (see Figs. 77 to 81).

The elephant (see Fig. 14) has a kind of chin, and among older writers in the pre-evolutionary days this fact was adduced as showing its superiority to other quadrupeds. But we now know that the elephant's chin is a mere degenerate remnant of the long lower jaw of his ancestors, the tetrabelodon (see Fig. 12) and the mastodon (see Fig. 13). In the illustrations to which reference is made the process of its downward evolution is plainly shown.

Another interesting example is found in the dugong and its relations (see Figs. 41 to 43). Here a little search into palaeontology shows that this apparent chin is not, like the elephant's, a relic of decayed functions, but that it has, like that of man, increased and improved with the ages. As seen in the illustrations, the dugong's collateral ancestor, the halitherium, and its big extinct relative, known as Steller's sea-cow (*Rhytina gigas*), had "chins" also, but in a less marked form. As a matter of fact the downward prolongation of the mandible in these animals is not a chin comparable with our own at all, but is merely a kind of bony rostrum on which the dugong and its relations wear their horny false teeth. This structure, with its curious change of angle, is more comparable to the bony support of the flamingo's bill than to a human chin. A very curious fact is that we appear to find the nearest resemblance in the whole animal world, whether ancient or modern, to our own mandible in a group of some of the earliest reptiles that have yet been discovered. In the Figs. 15 and 16 of those strange theromorphs, Pariasaurus and Inostransevia, unearthed by Prof. Amalitzky in the Permian strata on the shores of the northern Dwina, we see an extraordinary chin which resembles our own in several striking anatomical particulars.

How such a resemblance comes to exist I do not even venture to guess; but most assuredly Nature's molding forces, which so shaped the mandibles of these ancient reptiles, were totally different from those cerebral activities largely responsible for the chin of civilized man. We say so more confidently because casts of their skull-cavities show that they had no brains to speak of, the whole cerebral chamber being of about the same caliber as the tunnel for the spinal marrow.

A glance at the drawing of the mandible of a chim-

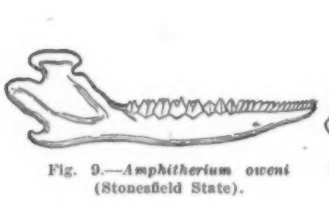


Fig. 9.—*Amphitherium oweni* (Stonesfield State).

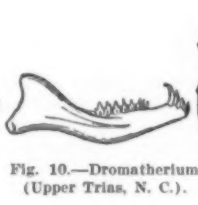


Fig. 10.—Dromatherium (Upper Trias, N. C.).

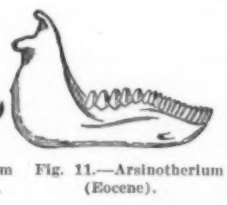


Fig. 11.—Arsinotherium (Eocene).

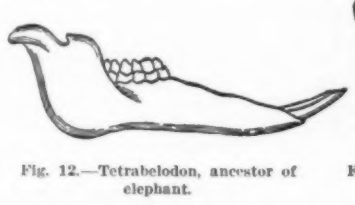


Fig. 12.—Tetrabelodon, ancestor of elephant.

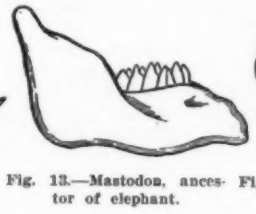


Fig. 13.—Mastodon, ancestor of elephant.

Fig. 14.—*Elephas primigenius.*

Fig. 15.—Pariasaurus.

Fig. 16.—Inostransevia.

I propose to discuss in the present article some of the causes which appear to be responsible for this curious deviation from type. That these causes were evolutionary factors of considerable potency becomes fairly evident when we examine further into the facts. The general type of the mandible among terrestrial vertebrates has been curiously uniform from the very earliest times, as may be seen in the illustrations of mesozoic and eocene jaws (see Figs. 9 to 11). It is, we may say, fixed or stereotyped to a remarkable degree. This makes the search for evolutionary forces which have so changed it in our own species all the more interesting.

There are certain apparent chins found among other vertebrates, a few typical instances of which, with their probable evolutionary causes, it may be interesting to discuss briefly.

* Reproduced from *Knowledge.*

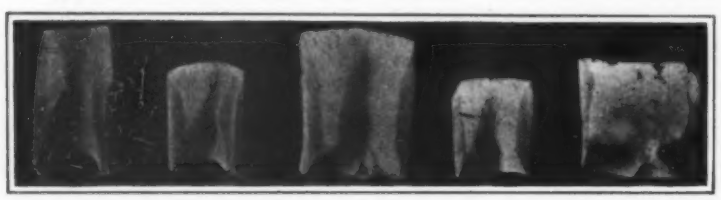


Fig. 17.—Fossil Lemur. Fig. 18.—Macaque monkey. Fig. 19.—Chimpanzee (young). Fig. 20.—Siamang gibbon. Fig. 21.—The Naulette jaw.

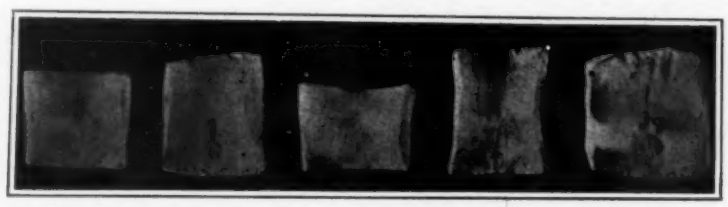


Fig. 22.—Pigmy, Central Africa. Fig. 23.—Bushman, S. Africa Fig. 24.—Hottentot, South Africa. Fig. 25.—Deaf Mute. Fig. 26.—An ordinary European.

Figs. 17—26 show the progressive stages from the beginning of the Genial Pit in the Lemur to the fully developed Genial Tubercles in modern civilized man.

Fig. 27.—Hottentot. Fig. 28.—Hottentot. Fig. 29.—Bushman. Fig. 30.—Hottentot. Fig. 31.—Bushman.

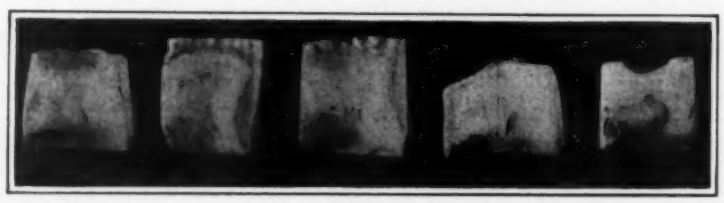


Fig. 32.—Hottentot. Fig. 33.—Bushman. Fig. 34.—Andaman Islander Fig. 35.—Veddah (Ceylon). Fig. 36.—Low type (W. Africa).

Figs. 27—36 show the imperfect development of Genial Tubercle and the persistence of the "Simian Pit" among certain low races with only imperfect articulate speech.

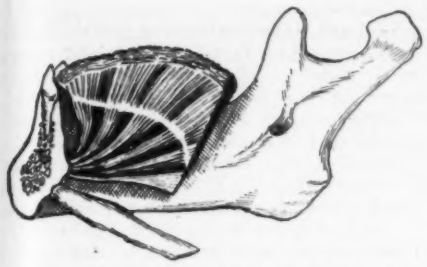


Fig. 37.—Human jawbone with part of the tongue, drawing showing the spreading *fasciculi* of the *genio-glossus* muscle, and their origin from the upper genial tubercle.

Fig. 38.—Transverse section through the tongue, diagram showing *genio-glossus* muscle penetrating the intrinsic muscles. After Quain.

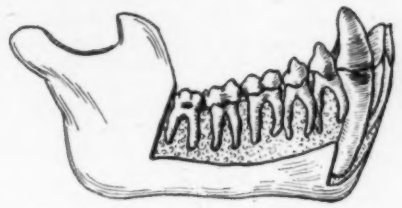


Fig. 39.—The jawbone of a chimpanzee, showing roots of teeth and the stout buttressed socket of the large canine tooth filling the side of the "chin."

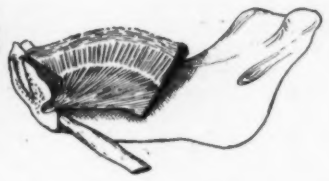


Fig. 40.—The lower jaw and tongue of a macaque, showing the deep pit for the origin of the *genio-glossus* muscle.

panzee (see Fig. 39) with the roots of the teeth exposed shows the real status of the chin in the anthropoids. It is mainly formed by two thick bony buttresses supporting the sockets of the lower canine teeth. This apparently was the real physical beginning of the bony chin, or rather was, as it were, the gross concrete foundation upon which evolutionary forces have based the modern structure.

It is a most remarkable and suggestive fact that after man (or the *infra-man*) had lost his huge lower canines, this abundance of bony tissue in the lower edge of the mandible did not disappear, but became more marked as an anatomical feature (see Fig. 37). From analogy with the elephant, such a degeneration should have taken place at once. That this did not happen is a proof that the part more than justified its continued existence by performing some function of vital importance to the species.

It is when we turn a human mandible round and look at it from the inside, and observe the surface beneath the central incisor teeth, that we begin to get hints as to the actual functions of the chin and the causes which have led to our deviation from ancestral type. About half-way between the rim of the central tooth-sockets and the lower edge there are to be found in practically all European and in most other jawbones two bony prominences known as the genial tubercles (see Fig. 26). Below them are two somewhat similar prominences, generally much smaller (which often appear as faint convergent ridges), which are also known to anatomists as genial tubercles; but these, I think, we need not consider of any importance in the present argument. They are to be found, not only in the lowest savages and in prehistoric men, but also in a large number of the apes and other vertebrates; indeed, I have detected apparent traces of them in those strange Permian reptiles of incalculable antiquity to which allusion was made above. They are the points of attachment for a little muscle which appears to be equally developed in man and in many of the lower creatures. It is known as the *genio-hyoideus*, and has no connection with the tongue.

A closer examination of the larger bony prominences, or the genial tubercles proper, reveals some very interesting and remarkable facts, especially when we employ comparative methods. To these are attached the tendon of the fanlike *genio-glossus* muscle which spreads out beneath the whole lower surface of the central region of the tongue, and penetrates through the intrinsic muscles almost to the upper surface (see Figs. 37 and 38). Now if we examine any of the current books on anatomy, little or no suggestion is found that the functions of the *genio-glossus* muscles have to do with articulate speech. Let us leave the mandible for a while and confine our attention to the structure and functions of this muscle, and I think it will soon become evident that it has more to do with the oral (as distinct from the laryngeal) machinery of articulate speech than any other structure.

In the diagrams (see Figs. 44 to 49), which show the under surface of the tongue of man and other creatures more or less related to him, it is seen how remarkably this muscle has become developed since we became human. The functions accorded to it in our standard works of anatomy would apply to the needs of the dog and the pig equally to those of man; yet we see that in these animals it is a mere feeble slip of flesh which can exercise but little influence.

I have dissected it in a good many apes, among which animals it evidently had somewhat important duties quite apart from vocal production; in fact, I doubt whether in any other creature except in man we should find the tongue interfering in any way whatever in the sounds which issue from the larynx. The muscle is not only much smaller in apes than in man, but it is much more homogeneous and compact (see Fig. 40); while, so far as I have been able to observe, the method of innervation shows an even greater difference than is seen in the structure of the muscle itself. To put the matter very briefly, in man the *genio-glossus* has become a series of a large number of independent muscular strips which are, to all intents and purposes, separate muscles, each with its little fiber of the hypoglossal nerve entering it in such a way as not to hamper its free movement, while in the apes it is apparently a single muscle, or a closely united group, acting *en bloc*.

It must be remembered that the adoption of an exceedingly important new method of expression and communication such as human articulate speech would

Fig. 41.—Jaw of Halitherium.

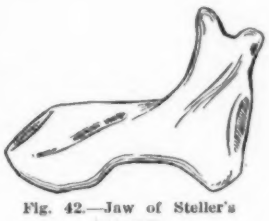


Fig. 42.—Jaw of Steller's sea cow.

Fig. 43.—Jaw of the Dugong.

Fig. 44.—Siamang.

Fig. 45.—Orang.

Fig. 46.—Chimpanzee.

Fig. 47.—Dog.

Fig. 48.—Man.

Fig. 49.—Pig.

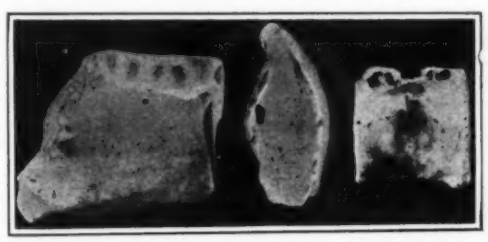


Fig. 50.—The Piltdown jaw, recently discovered.

Fig. 51.—Profile Heidelberg jaw.

Fig. 52.—Central African pigmy.

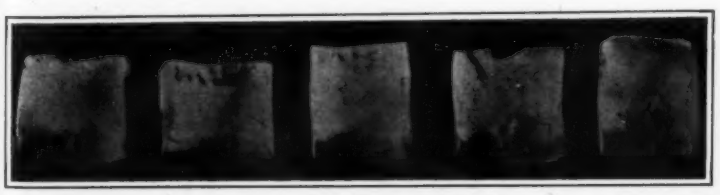


Fig. 53.—Bushman with tubercles.

Fig. 54.—European child (six years old).

Fig. 55.—European child (fourteen years old).

Fig. 56.—European child (sixteen years old).

Fig 57.—Ancient Egyptian, with tubercles.

Figs. 53—57 show the development of the tubercles in young Europeans compared with those well developed in savage and civilized people.

Fig. 63.—Tasmanian.

Fig. 64.—Australian.

Fig. 65.—The prehistoric Heidelberg jaw.

Fig. 66.—O'Brien, the Irish giant.

Figs. 65—66 show the contrast between the prehistoric type and the well-developed modern type. Fig. 66 is a particularly fine specimen.

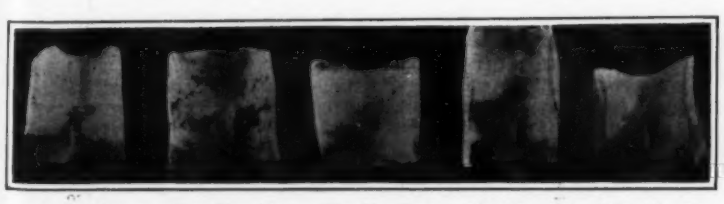


Fig. 58.—Fuegian.

Fig. 59.—Aino race.

Fig. 60.—Bushman.

Fig. 61.—Hottentot.

Fig. 62.—Bengali.

Figs. 58—64 afford a study of the remarkable variety of the tubercles in different races.

Fig. 67.—Maori specimen.

Fig. 68.—Japanese.

Fig. 69.—Tartar.

Fig. 70.—Malay.

Fig. 71.—Chinese.

Figs. 68—71 show the general similarity in races that are somewhat akin in blood and language.

require widespread and most elaborate changes in the structures which it brought into play. It is not possible on the present occasion to go into the marvelously intricate cerebral, nervous, and muscular machinery, with its innumerable bonds of co-ordination required for ordinary speech; but a little search into the matter will show anyone that we are here in contact with one of the most incredible marvels in nature. Most wonderful of all, the whole mechanism is, from an evolutionary standpoint, *quite new*, a product of merely the later fragment of a brief geological period!

When we consider the number of movements, following one another in continually varying order, required for articulate speech, it is obvious that only machinery which is able to act with every mechanical advantage and with a minimum of friction, can

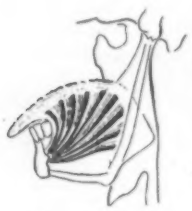


Fig. 72.—Diagram of the *genio-glossus* muscle, showing it at rest.

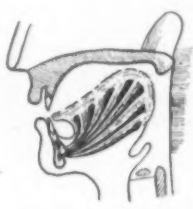


Fig. 73.—Diagram of the *genio-glossus* muscle in pronouncing the sound "Oo."

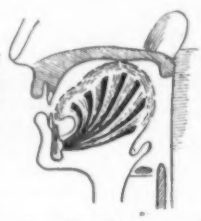


Fig. 74.—Diagram of the *genio-glossus* muscle pronouncing the letter "K."

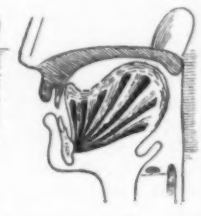


Fig. 75.—Diagram of the *genio-glossus* muscle in pronouncing the letter "T."

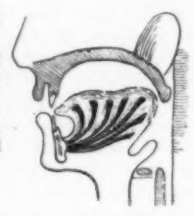


Fig. 76.—Diagram the *genio-glossus* muscle in pronouncing "Ah."

accomplish such a task with precision. Public speakers frequently talk at the rate of one hundred and fifty words a minute, while it seems possible to articulate quite clearly and correctly when speaking at the rate of one hundred and eighty words a minute. If we analyze the action of the tongue when speaking at the rate of one hundred and fifty words a minute, we find that there must be at least five hundred different movements or adjustments. This gives eight or nine in every second! Such movements, it must be remembered, do not follow one another regularly in mechanical rotation like the piston-beats of a multiple-cylindered engine, but are continually varying their order. What wonder is it that co-ordination sometimes breaks down, with the result of a stutter or a stammer?

Now a brief examination of the intrinsic muscles of the tongue, i. e., those that begin and end in the tongue itself like the distal muscles of an elephant's trunk, will show how totally inadequate these would be to produce any such result; but immediately one takes careful note of the mode of action of the *genio-glossus* muscle the solution of the tongue's incredible agility becomes possible.

It is seen in the accompanying diagrams (see Figs. 72 to 76) that the several bundles, or *fasciculi*, of the muscles are able to act more or less at right angles to the main plane of the tongue without anything to hamper them. For each flashlike movement of the tongue away from the palate all that is demanded is an instantaneous shortening of one or other of these independent strips. For instance, in pronouncing the letter T we place the tip of the tongue against the palate close to the upper incisor teeth (see Fig. 75), and then snatch it away with great rapidity. The placing it there is probably the work of the intrinsic muscle called the superior longitudinal lingual, but the more critical action of withdrawing it at the proper moment is due to the front fibers of the *genio-glossus, which become taut and braced for instantaneous action as soon as the tongue-tip is pressed against the palate.*

In Fig. 74 it is seen that in the hard G or K exactly the same thing takes place with the central *fasciculi* of the muscle. A like action comes in with sounds involving L, N. R, D, J, Q; while in S, X, and all other consonants where the nice adjustment of the distance of the tongue from the palate is a matter of moment the *genio-glossus* muscle is capable, and appears to be the only structure capable, of exercising a quick and exact control. The same applies to the vowels, as is well shown in the accompanying diagrams after Von Meyer's drawings. Von Meyer, however, has not shown the *genio-glossus* muscle in action, as it is shown here, and indeed, strangely enough, does not give it a word of mention as a factor in articulate speech.

It is worth while to take note of the fact that practically all the speech-movements of the tongue take place in the neighborhood of its central line, and that the sides play a very subordinate part. Hence, the other extrinsic muscles, such as the *hyo-glossus* and *stylo-glossus*, can have little or no part in articulation (see Fig. 38).

Now let us return to our inferior maxilla and examine the attachments and relations of the *genio-glossus*. It is obvious that for quick, precise movements, such as those demanded by articulate speech, it must be unhampered and have plenty of room to act. An examination of the arrangements for the play of the muscle in different animals is exceedingly instructive. In the dog, and indeed the majority of the mammalia, the tongue lies flat upon the lower jawbone, leaving practically no room for any muscular machinery. If, however, a photograph of a plaster cast of the inner surface of the wolf's jaw (see Fig. 5) is compared with that of the baboon (see Figs. 7 and 8), which outwardly resembles it, a remarkable difference of shape is evident.

In all the monkeys, and even lower down the scale among the lemurs, we find that nature has made provision for working room for the *genio-glossus* muscle by excavating a kind of pit on the inner surface of the mandible beneath the tongue. This pit has been noticed by various comparative anatomists, but I had never seen any explanation of the reason why it exists, nor was I aware of its function, until a series of dissections of monkeys' jaws showed in every case the tiny tendon of the *genio-glossus* coming from the lower surface of the deepest part of the pit (see Figs. 42 and 40). The more doglike the jaw is, as in the baboons, the more, in fact, it corresponds in general outline with the prevalent type of the mandible among lower vertebrates, the deeper is this pit. As soon, however, as the mandible begins in some degree to resemble our own, as in some chimpanzees and gibbons, and the whole lower surface becomes tilted forward, the pit seems to be no longer needed, and becomes shallower. One may as well remark in passing that it is, of course, obvious that originally the *genio-glossus* muscle had nothing whatever to do with articulate speech. The need it met in the economy of lemurs and apes was probably that of giving increased mobility to the tongue for sorting food already in the mouth. This is plainly seen when we give a monkey a nut and see him crack it and turn it about with his tongue, selecting the kernel and rejecting every fragment of shell. This ability common among all the Primates to sort food with the tongue, and with its aid to eschew unacceptable morsels, is strikingly absent in the case of most animals. Anyone can assure himself of this on seeing a dog try to get rid of some small unpalatable object. Animals such as cattle, and especially camels and giraffes, which are liable to get dangerous thorns into their mouths, depend upon a most elaborate arrangement of the long papillae lining their cheeks, so that by a simple backward and forward movement of the tongue such things are at length extruded.

There seems little doubt but that it is this sorting machinery of the tongue in the lower Primates which has been seized upon and greatly elaborated for the new and wondrous mechanism of articulate speech.

Before going further it may be as well to clear up another point which seems to have puzzled some of my audience when I was lecturing at the recent British Association meeting. The question was asked me: "How is a parrot able to talk if he has no chin?" An equally pertinent question would be: "How is a phonograph able to talk when it possesses no chin?" A parrot has deep down behind its breastbone a marvelously elaborate and versatile sound-producing apparatus, almost as different from any possessed by ourselves as is the mechanism of a phonograph. When man began to speak, he had to make use of raw material, *which was there already*, to build up his talking machinery. That the parrot and the phonograph can speak, merely proves that there are other ways of doing it; but the only question which we here have to discuss is how man did it himself with such means as were at his disposal.

When we come to examine the difference between prehistoric man and modern savages we find the same order of structural change in the mandible still going on, tending to the greater efficiency of the *genio-glossus* muscle for speaking purposes. When this fanlike group of muscular fibers came out of a deep pit, such as is seen in the illustration of the jaws of the lower monkeys, the fibers were obviously hampered by being bunched and huddled together (see Fig. 40). As the jaw became tilted forward, giving more engine room beneath the tongue, the need for the pit became less, and it becomes shallower and shallower until we find it a mere depression, as in the Saimang gibbon (see Fig. 20). These changes are plainly shown in the series of plaster casts of which photographs are reproduced in Figs. 17 to 26. First of all is a fossil lemur, in which the jaw still retains its generalized character, but is beginning to show depressions as the genial pit makes its appearance; then come apes like the baboons, macaques, or colobus monkeys with an exceedingly deep pit or depression. Next we find anthropoids, in which the lower edge of the jaw is already being dropped into something resembling a chin, and the depression at once becomes less apparent. Next are some jawbones of prehistoric man, namely, the Heidelberg and the Naulette jaws, in which the depression is still plainly seen and is scarcely less marked than in the gibbon.

It will be seen that the Heidelberg jaw shows on its surface a tubercle; indeed, I understand that one of the descriptions of it published soon after it was found stated that it did not differ from modern jaws in this respect (see Fig. 65). A brief comparison with the other casts, however, will make it plain that the tubercle here seen is too low down to be that for the *genio-glossus*, and is plainly the one for the *genio-hyoid* muscle mentioned in the earlier part of this article, which has nothing whatever to do with the tongue. This tubercle is quite common among the apes.

When we come to the Pygmies and Bushmen we find in the majority of jaws the remains of this pit or a mere flat surface; but in some African dwarf races, and among the Hottentots, Veddahs, and Andamanese, two little prominences are seen beginning to grow at the lower edge of the pit (see Figs. 27 to 36). These tubercles, as we pass to higher and more civilized races, become more and more prominent, until we get the European type familiar to all students of anatomy.

Now the bearing of these changes on the functions of the *genio-glossus* muscle is fairly evident. First of all, it needed a deep pit in the lower apes to get room to work at all. Then the depth of the pit became unnecessary through the tilting of the lower surface of the mandible; and by means of this change the muscle was obviously given greater freedom for action. Then we get a nearly flat surface; and finally a prominence appears, enabling the separate *facsiculi* of the muscle to spread from the very point of origin and so act independently without hampering their neighbors (see Figs. 26, 56, 62, and 66).

We are thus able to follow the whole course of the history of the *genio-glossus* muscle from fossil lemurs to modern men, and a very remarkable history it is, difficult, I believe, to parallel in any other structure of the body which we may pick out for the purpose. We found it in the lower apes, in which it first appears as an important factor in tongue movements, coming out of a hole in the lower jaw, and we take leave of it mounted upon a pinnacle quite as high as the pit was deep (see Figs. 37 and 40.) The muscle might stand above all things else in our bodies as a symbol and sign of our upward progress. For I think it can-

Fig. 77.—Chimpanzee.

Fig. 78.—Siamang.

Fig. 79.—Heidelberg.

Fig. 80.—Neander type.

Fig. 81.—Modern man.

not be denied that its development marched *pari passu* with the development of intellectual capacities and the increasing need of a means of clear expression.

When speech began, as distinct from mere animal stereotyped cries and other noises, it is, of course, impossible to say. For the speech of certain low savages, consisting of grunts, guttural sounds, and clicks, it is fairly obvious that few tongue movements are necessary; but wherever languages have become more elaborate, and many of them in different parts of the world appear to have had an independent origin from more brute-like utterances, we find that the *genio-glossus* muscle comes more and more into play, as is evidenced by its tubercles of attachment and by the forward tilt of the chin to give elbow room among all the higher races.

The speech of monkeys is, of course, a myth, and most of our anthropoid friends are curiously silent beings. The two exceptions appear to be the chimpanzee, which is described by travelers as shouting and calling in varied tones in the forest, and certain gibbons, which appear to come nearer to us in the variety of articulate utterances than any other of the Primates. From the series of plaster casts shown in the figures, and in many others that are in my possession, it seems to become evident that, speaking generally, the genial tubercles may be taken as some index of social and intellectual development. They are not, of course, strictly necessary for speech, but it is clear, both from anatomical and general reasons, that they greatly facilitate speech.

It is interesting to watch their development in the normal human subject (see Figs. 54 to 56), and I have several casts which illustrate this fairly clearly. In all young children they are absent, and up to the age of fourteen years they make but a small show; in fact, the jaw of a child of fourteen years almost exactly resembles in this respect that of a Bushman or Pygmy; between fourteen and seventeen, however, they appear to obtain their full development. How far that development is dependent upon the use of the muscle it is difficult to say; my own belief is that, like many of the roughnesses and ridges upon our bones, they are very largely the product of vigorous muscular action, i. e., nature has met the obvious need of the muscle by altering the bone in a certain specific direction.

For many years I have been endeavoring to get evidence as to the presence or absence of the tubercles in deaf mutes. Such as I have, so far as it goes, seems to show that in adults who have never acquired articulate speech they are quite absent (see Fig. 25). In the one specimen I have from a deaf mute, the bone almost exactly resembles that of a Bushman, or a child of fourteen.

A glance over the peculiarities of the tubercles in the accompanying figures shows how extraordinarily variable they are in different individuals and in different races (see Figs. 58 and 59), but before any safe generalized conclusions are drawn from these diversities one ought to have many thousands before one for comparison. It seems to me quite probable that this would prove a fruitful line of research for anyone with leisure and opportunity to follow up; for, when we consider the distinct anatomical problems involved in the pronouncing of different languages it seems not improbable that definite structural peculiarities might become apparent in accordance with the "tongue" spoken. We know that it is practically impossible for Europeans to acquire the elaborate tongue and throat movements of not a few barbarous languages, and it would be extraordinary indeed if this wide diversity in muscular function did not leave some trace which the methods of the anatomist might reveal.

In Fig. 66 is reproduced a photograph of a cast from a part of the jawbone of O'Brien, the Irish giant, the capture of whose body gave John Hunter so much trouble. I placed it there, because it shows the typical arrangement of the genial tubercles in a very marked manner. It also tells us something else, which I think is not a little instructive. There can be no question that the Irish speak our language with much greater precision than the average Anglo-Saxon, and further investigations seemed to show that in Irish jaws there was a fuller development of the genial tubercles than in those found in English museums. On following the same line of research a little further it become apparent that a greater symmetry and uniformity of the development of the genial tubercles was to be found in French and Italian jaws than in English. This seems to the writer to be a matter well worth following up.

The Fixation of Nitrogen*

Progress in Scandinavia

ONE of the most striking developments in recent times in the electro-chemical industries has been the use of calcium carbide on a commercial basis as a medium for the fixation of atmospheric nitrogen with the formation of calcium cyanamide, which in turn is now to be utilized on a manufacturing scale as a substance for the production of nitric acid by the oxidation of ammonia in the presence of heated platinum. From the purely scientific point of view none of the processes is new. The various reactions involved were accomplished in laboratory experiments long ago. The interest attaches therefore to the steps which have made commercially possible the chemical reactions well known to the scientific worker. Calcium carbide—a combination of carbon and lime—has been in use for a long time as a source from which acetylene gas could be generated for lighting and welding; and although it was known that when 20 per cent of nitrogen was added to it the result was cyanamide, or mitrolim—a fertilizer of great value—there was the serious disadvantage that carbide was not produced at a sufficiently low cost to enable the resultant cyanamide to compete with Chile nitrate. All this has been changed, and there seems now no fear of any failure to meet the undoubted need for nitrogenous fertilizers, which must increase greatly if the world's growing population is to be fed despite the natural inproverishment of the soil.

FORMATION OF CYANAMIDE.

The first efforts to fix nitrogen in association with carbide on a commercial scale were by passing air over heated copper; the oxygen was absorbed, and the free nitrogen liberated was led into retorts which contained the carbide in a powdered state, the reaction giving cyanamide. But the desired economy in production was achieved only when the Linde process was applied for the liquefaction of atmospheric air by mechanical means. Once liquid air was obtained it became possible by rectification or distillation to separate the oxygen and nitrogen, since the boiling point of the former is lower than the latter. The adoption of this process on a large scale and the utilization of water power in great volume to carry on manufacture in huge quantities have together greatly reduced costs.

These steps were the result of the formation in 1906 of the Alby United Carbide Factories. Having reorganized their plant at Alby in Sweden, and adopted the Linde process, they later established new works at Odda, on the west coast of Norway, where immense amounts of hydro-electric power are available, for the making of calcium carbide. An associated company, the Northwestern Cyanamide Company, took the greater proportion of this carbide and formed cyanamide, or nitrolim, utilizing the Linde process of manufacturing the nitrogen. Since the new works were started five years ago there has been almost continual development not only in the volume of production but also in the perfection of the process to ensure regularity in the chemical contents of the product and economy in output. New uses for the cyanamide were also discovered whereby nitric acid can be economically produced. At the same time new factories are being established, others are in contemplation, and ultimately the company will have an annual output rivaling the whole natural supply from Chile.

POWER SUPPLY.

In the process cheap electric power is a fundamental consideration, and thus it is that the principal works are in Norway, and preferably on the seaboard, so that the transport of the raw material and finished product is not so expensive as would be the case were inland waterfalls utilized. The choice of Odda was influenced by the existence of a company to construct a power station at Tyssefaldene, three miles from Odda. The watershed extends to 378 square kilograms, the average annual rainfall being 49 inches and the head of water 1,269 feet. The first installation was of about 30,000 horse-power in seven units; now there is 83,000 horse-power in use, and extensions are being pushed forward to increase the amount to 125,000 horse-power. These works include the heightening by 15 meters of the dam which stores up the water in the lake on the mountain top. Some idea of the magnitude of the work is afforded by the fact that this dam impounds water equal to 80 per cent of that stored by the great Assuan dam on the Nile. Again, there is sufficient storage to run full load for five years without snow or rainfall. The water is conveyed through two tunnels from each of two lakes, the intake being at the bottom so as to insure supply during the winter when the lakes are icebound. The larger generating units are now each of 12,500 kilowatt at 120 revolutions per minute; the new units will be of 15,000 kilowatt. The current generated is three-phase, and it is transmitted at 12,000 volts, and by static transformers, exceptionally well ventilated in view of their great size, reduced at the carbide furnaces to 50 volts and at the cyanamide furnaces to 60 or 75 volts. The current is bought in bulk at Odda, but in the newer works the carbide and cyanamide works will posses their own hydro-electric power supply stations.

CARBIDE FURNACES.

The most important feature in the carbide factory is the electric furnaces. Originally there were 10 of these, each producing continuously seven to eight tons of calcium carbide in 24 hours; but 10 more have recently been added, each of a capacity of 16 to 18 tons a day. The electrodes of the former utilize 1,400 kilowatt and of the latter 3,500 kilowatt, and the temperature maintained is 5,720 deg. Fahr. The charging with powdered anthracite and burnt lime is almost continuous, and the tapping of the molten calcium carbide is at intervals of 45 minutes. The material is conveyed in trays to a cooling bed, crushed in a separate plant to the sizes required by the market, and subsequently filled into tinned drums enclosed in barrels for dispatch. Up till recently the annual output at Odda was 32,000 tons, but now it is 80,000 tons.

Associated with this increase is a great improvement in the electric furnace, whereby the efficiency is increased. The new furnaces are so built that the radiation of heat is less than from a steam boiler, the charging is automatic, and the internal distribution such as to obviate waste heat at the top, while the products of combustion are drawn off for utilization in the limekilns instead of producer-gas. There is thus not only increased economy, but the contamination of the atmosphere due to the escape of gases and smoke is reduced to a minimum.

The preponderating proportion of the calcium carbide is passed direct to the cyanamide works. There, also, great developments have been made. The Linde process plant is the largest installation in the world, liquefying 100 tons of atmospheric air a day, from which is obtained 77 tons of nitrogen, which is utilized not only in the production of the cyanamide in the electric furnaces, but also throughout the operation of crushing the carbide prior to the fixation of the nitrogen and throughout the grinding of the cyanamide to sizes to meet market requirements. Since the works were opened four years ago the number of furnaces has been increased nearly sevenfold, the annual output of the Odda factory being now 80,000 tons of cyanamide. The furnaces have been greatly improved in design. They are of one ton capacity, and electrical current at 60 to 75 volts is applied through an electrode in the center, while nitrogen is applied through valves at the side. By the maintenance of a temperature of 1,650 deg. Fahr. cyanamide containing 20 per cent of nitrogen, 12 per cent of free carbon, 60 per cent of lime, free and chemically combined, and 8 per cent of inert substances is obtained.

PRODUCTION OF NITRIC ACID.

While cyanamide is being increasingly used in this form as a fertilizer throughout the world, the most recent and important development is its utilization for the production of ammonium salts and nitric acid. Although in 1830 it was shown, by laboratory experiments, that nitric acid could be catalytically produced by the action of platinum on ammonia in the presence of air, the fact had no commercial significance, as there was no source of ammonia at reasonable prices. By his experiments in 1900 Dr. Ostwald succeeded in producing nitric acid from ammonia by means of superheated steam, and later, at works in Belgium the process was further developed so as to obtain ammonia from cyanamide—the source of the cheapest form of chemically pure ammonia. This discovery enabled nitric acid, nitrate of ammonia, and other important subsidiary compounds to be produced chemically and economically, and at the same time removed all doubt as to future supplies. A large company known as the Nitrogen Products and Carbide (Limited) was formed not only to acquire the rights of the new process for the whole world, excepting Westphalia and Rhineland, and to establish works for the manufacture of nitric acid, nitrate of ammonia, etc., but to develop existing carbide and cyanamide factories. The increased producing capacity of the works at Alby and Odda is a direct result. Entirely new works are now in process of construction at Aura—a hydro-electric power station—and the first unit of 100,000 horse-power is being installed with carbide and cyanamide furnaces to make 200,000 tons annually of cyanamide. The company have also purchased waterfalls at Toke and Blekestad-Bratland, so that with the Aura works 600,000 horse-power more will be available in Norway. The company further possess the Dettifoss water rights in Iceland, where 400,000 horse-power will be available. The several waterfalls will be "harnessed" as the demand for cyanamide justifies successive steps, the full possibility at present contemplated being nearly two million tons of cyanamide a year.

MANUFACTURE OF EXPLOSIVES.

The likelihood of increased demand is obvious from what has been stated, especially when the variety of applications of nitrates is taken into consideration. Of first significance is its use for explosives for peace and war purposes. At present the essential constituents of gun projectile propellants are nitro-cellulose and nitroglycerine, requiring nitric acid for their production. Dependence on the supply of the raw material from overseas sources involves an element of danger in war times. It has therefore been decided to establish works on the Thames at Dagenham for producing from cyanamide 12,000 tons of nitric acid a year, at Trafford Park, Manchester, for a like capacity, in Scotland for 9,000 tons output, and in Ireland for a production of 3,000 tons. Large stores of cyanamide will be kept; but as a last resort the ammoniacal liquors from coke ovens, blast furnaces, residual recovery plant, and gasworks may be used by the same process instead of cyanamide. It is the intention also to make nitric acid at the cyanamide works in Norway.

By the new process cyanamide is also utilizable in the manufacture of sulphuric acid, as the raw material for cyanides such as ferro-cyanide, sodium and potassium cyanides, and for the production of urea and guanadine salts used for a variety of purposes in the production of synthetic dyes and other chemical products.

* Reproduced from the Engineering Supplement of the London *Times*.

Fig. 1.—True brush discharge.

The Brush Discharge*

A Phenomenon Little Discussed in Electrical Literature

By A. Vosmaer

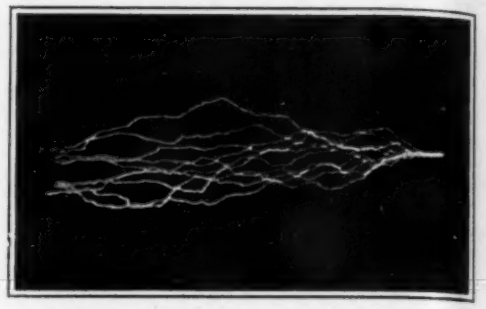


Fig. 2.—Series of ten consecutive sparks.

THE literature on the brush discharge is very scarce. Most scientists work on too small a scale, while practical men have neither the time nor the opportunity to study the brush discharge as such. For this reason I hope that the following account of my personal experience of fifteen years with brush discharge phenomena will be found useful.

PART I.—THE BRUSH DISCHARGE THROUGH AIR WITHOUT THE USE OF SOLID DIELECTRICS.

There is perhaps no essential difference between the passage of electricity in a solid, a liquid or a gas, although it is customary to call the first conduction, the second electrolytic (ionic) conduction and the third convection. It would perhaps be better to consider all of them to be convective in character.

In any case a potential difference between the two points considered is essential for a current; if there is no P. D. there will be no current. It is immaterial whether we think of P. D. as the first cause or whether we look upon resistance as the essential for a P. D. again.

In the whole of physics the rule holds that there can be no force exerted unless there is a resistance against which said force can be applied. Sometimes action creates its own reaction (static back pressure). There is a general tendency in nature to reduce all "free energy" to a minimum, thereby increasing the entropy to a maximum; all water at a high level will run downward; all differences in temperature will be equalized at the cost of the higher temperature; never will any amount of heat as measured by heat units be capable of raising the temperature of something that has a higher temperature. In one word, in nature's free state all energy change is in the direction toward decrease of intensity and increase of capacity.

Now if said change is not checked in some way or another it will exhibit itself; the usual way of checking is by means of the unknown entity called resistance.

Ohm's famous law is usually expressed by saying that the current is the quotient of tension and resistance, but it would be more logical to say that tension is the product of current into resistance. The first way, however, is much more convenient when reasoning in a popular way upon some common thing.

A potential difference, however small, even when infinitesimal, will always cause a current of electricity to flow through a solid conductor (if we may use the term of flow). But this is not true for an electrolytic conductor, in which case the impressed electric motor force has to be greater than the counter electric motor force of polarization in order to produce a current.

In gases the problem is still much more complicated as we shall learn. We may neglect the counter electric motor force, but there is a lower limit of electric motor force below which no current will pass through a gas. The value of this lower limit of electric motor force varies with such factors as the temperature, the degree of ionization, the shape and state of electrodes, etc. Therefore, the value of this lower limit is not a constant at all and cannot be given even approximately. It may be in the neighborhood of a hundred volts, or much higher.

The discharge of electricity in a gaseous medium depends on a number of factors, such as the pressure of the gas, its temperature, its nature. Further, it depends on the shape, on the size and spacing of the electrodes, and on the finish of each of them. Moreover, there are some secondary influences such as radiation (ultra-violet light) and the effects of a magnetic field or an electric field. It also depends on the kind of current supply, its tension, frequency, wave form and the circuit as a whole.

We shall discuss these influences in succession. Evidently the problem is rather a complicated one, so that we shall leave out of consideration many important details.

PRESSURE.

In the first place we shall have to confine ourselves to the study of the discharge in a space filled with gas and will not consider the phenomena in vacua, as these would form a treatise many times the length of this one.

It may be mentioned that a pressure lower than the atmospheric, greatly facilitates the passage of a current down to a certain point where there is so little gas left that there are not enough ions to convey the electricity.

The brush discharge is affected in such a way that

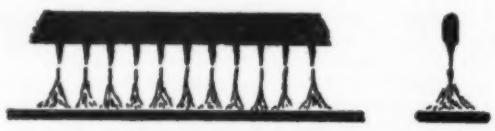


Fig. 3.—Brush discharge.

even a small diminution of pressure changes its character altogether. In view of this fact, one may feel inclined to try higher pressures. But the same holds true there, though in a less degree. We have tried up to three atmospheres, but every increase in pressure seemed to make it more difficult for the brush to keep up its being.

Watson, when constructing his high-tension voltmeter, has taken advantage of the fact that at high pressures gases become insulators. They are very poor conductors when liquified; the conductivity of liquefied gases is of the same order as that of pure water.

TEMPERATURE.

I have had no occasion to experiment either with very high or with very low temperatures, but it is probable that the first will be detrimental to a true brush discharge and the second will not have much effect until extreme temperatures are reached.

MOISTURE.

It is several years ago that Steinmetz, experimenting on high-tension sparks, published the result that moisture has little effect on the dielectric strength of air, and what influence it has points to increase rather than decrease as one would suspect at first thought. The brush discharge does not seem to be sensitive to moisture; although there is some evidence pointing in the direction of decrease of P. D. for the same brush, I would not dare to claim this as a fact.

KIND OF GAS.

Since the object of my researches has been the manufacture of ozone, I have always been experimenting with air or oxygen and have not tried other gases except hydrogen and carbonic acid. No marked change in the character of the brush could be detected when going but superficially into this matter. It would have been very interesting to know just what happens when other gases are subjected to the very strong influences of the brush discharge, but the scope of my work was already too big so that I could not go too far beyond it.

IONIZATION.

It is a very strange fact that though the brush discharge is powerful it does not seem to have much force of ionization. When a discharge of as much as 100 watts was confined in a small tube of glass and the air blown to a charged electroscope, after having been filtered through cottonwool, it did not change the position of the gold leaves, no matter whether they were negatively or positively charged.

This result surprised and annoyed me because I had expected to be able to prove that the brush discharge is essentially a positive one. I have every evidence that it is a discharge from the positive wave and not from the negative, but there are many investigators who hold the reverse to be true.

KIND OF DISCHARGES.

Before proceeding I wish to call particular attention to the fact that for the present moment we are considering discharges in free air, no solid dielectric being between the electrodes; the latter case will be considered afterward.

In free air, then, at atmospheric pressure and normal temperature, there are four distinctly different kinds of discharges, viz., the glow, the brush, the spark and the arc. The *glow* is the first stage. It is merely a bright spot on the electrode and causes[1] no appreciable loss of energy unless very prominent, in which case it is very liable to become a brush.

The interest in the glow discharge has greatly increased since in high-tension power transmissions the voltage has been varied so much as to bring about the corona effect.

There is much information now to be had on this subject of the corona effect which a few years back had no interest for the practical men. The corona loss starts at the point when the glow is about changing to the brush. There is no sharp line of demarkation between the glow and the brush discharges, though in their most characteristic forms they show no resemblance to each other.

The true *brush* (a photograph of which is reproduced in Fig. 1) has very distinct features. Its color is a dark bluish violet, its hissing sound and "wind" are well known,[2] its shape is a straight stem detached from the electrode from which it starts or rather separated from it by a dark space, and at its end there is a widely spread out cone. This cone or conical end may be flattened into a fan-shaped end, but not in all directions.

It is very important to remember this special form of the brush, as it gives a clue to many phenomena which are apt to appear when one is building up an ozone apparatus.

Fig. 4.—Spark mixed with brush discharge.

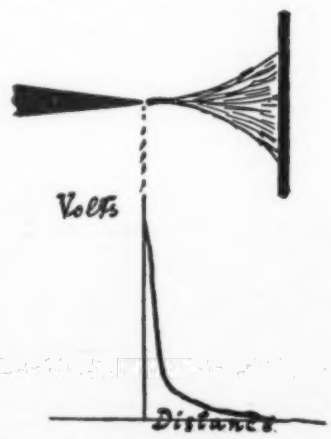


Fig. 5.—Brush discharge and potential gradient.

Fig. 6.—Positive brush (left) and negative discharge (right).

* Reproduced from *Metallurgical and Chemical Engineering*.

[1] The corona loss, which is caused by the glow discharge, is but small compared to what it would be were it a brush discharge.

[2] The names, Silent Discharge and Dark Discharge should be dropped.

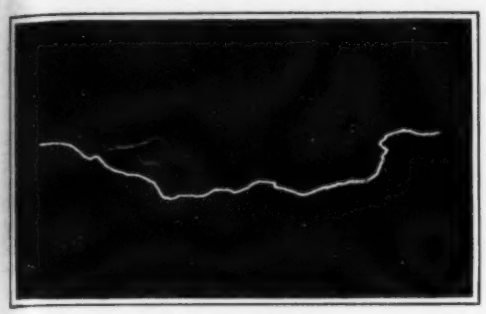


Fig. 7.—Spark.

The ignorance of this particular behavior of the brush accounts for many a failure in actual practice of ozonators, as we shall presently see.

The brush is a three-dimensional discharge; at the best it may be reduced apparently to two dimensions, that is, it may be flattened in one direction so that it looks as though it had no thickness. Still one should never lose sight of the fact that it has to have some extension in space in all directions. For practical purposes this means that one cannot possibly have a continuous line of discharge. There must be free space left between the different discharges, or in other words, it is necessary not to use a perfect smooth line, like a razor blade, but a dented one, for the discharger. Fig. 3 explains this sufficiently. It has been exaggerated purposely. In actual praxis, using 1.3 millions of points for a 20-kilowatt apparatus, there were 36 points used per inch. Sharper and longer points allow to use 50 points per inch. All this refers only to spacing in one direction. We shall see later on what the spacing has to be in the other direction, that one being more evident on account of the visible spread out at the base.

The brush discharge passes over again into the *spark* without a sharp boundary between them, although here again the brush and the spark, in their most characteristic forms, do not have any resemblance. The spark is characterized by its white yellow color, its peculiar zig-zag path, which under certain circumstances can be made straight, its loud report and its oscillatory motion, in contrast to the brush which is unidirectional and not intermittent.

Fig. 7 shows a photograph of a spark of 10 inches in length given off by a powerful 12-plate Whimshurst machine. Fig. 4 shows the mixing of a spark and some faint brush discharge from the same machine, run without its condensers. Fig. 2 represents a series of ten consecutive sparks.

If circumstances are such as to allow of it, a spark will change to an *arc*. This is the most dangerous of all forms of discharges on account of the tremendous amount of energy transformed into heat and concentrated in a small space; it generally means ruin of the apparatus unless checked in due time or taken care of and controlled by some method such as those now used in the systems of making nitrous compounds out of the air.

We shall not discuss in detail all these discharges, but had to mention them because we shall have to refer to them.

The arc (Fig. 8) is very hard to photograph because it is so restlessly moving about. Its characterstic features are its faint blue color, its intense heat and its continuity.

POLARITY.

When we speak of the brush we always mean the positive brush because there is no real negative brush, although there is a negative discharge under the same circumstances. In Fig. 6 we show side to side the positive and the negative discharge. The difference in appearance is striking, but could have been shown even much more strikingly had I taken other prints.

If matters are arranged in such a way that the pointed discharger is made the negative pole, all we obtain instead of the beautiful brush is a tiny little violet spot about one tenth the size of the positive brush or sometimes even less than that. The demonstration of this very marked difference is quite easily made. It used to strike most scientists who watched it. A powerful Rhumkorff induction coil is the best source of supply for this experiment, as it gives practically unidirectional high-tension current, the intermissions are too short to be noticed, and if the output is taken up by a good number of points, say several thousand, then there is no interference from undesired sparking. It is known that a Rhumkorff gives a secondary current of very peculiar wave form but that is no objection.

ELECTRODES.

(1) *Shape and Size of Electrodes.*—There are many variations to be tried. First let us take two flat surfaces, the discharge invariably will take place at the edge because here the situation differs from that at other points, the electric charge being greatest at the edge. In the center of said flat surfaces there can be no discharge whatever, while from the edges an irregular, rather poorly developed brush may occasionally start.

The next experiment is to take two spheres. There can be no brush discharge under ordinary circumstances of operation. If the spheres are of equal size, the equipotential surfaces have the form of spherical shells or rather ellipsoidal shells, quite unfit for our purpose. Two parallel wires are unsuitable for the purpose of the brush discharge for the same reason, namely, the fact that the equipotential surfaces are coaxial with the wires. Two crossing wires may give rise to a brush, but will not do so unless very carefully arranged. As a rule a wire is a very bad shape for a brush and this is fortunate, since this is the reason why after all the corona loss does not amount to very much even on very high tension.

Two points cannot give off a brush discharge, unless under very special circumstances; it is very difficult to obtain a brush and it is impossible to work with it. All these facts are easily told, yet, until we understand the exact conditions of the true brush, they seem puzzling.

If we refer to Fig. 1 it is easily understood that the arrangements of electrodes just summed up cannot give a brush discharge. Since the origin and end of the discharge are different, the two electrodes should also be made different; that is, we must not take two electrodes of *equal* but of *different* shape.

Let us now consider these cases and also take into consideration another circumstance, viz., that of sign or polarity. A great many combinations could be

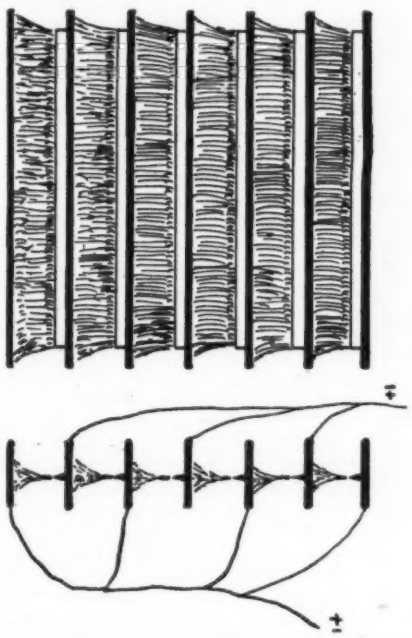


Fig. 9.—Arrangement of discharge.

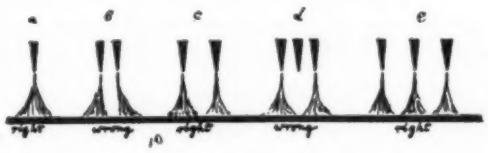


Fig. 10.—Spacing of discharges.

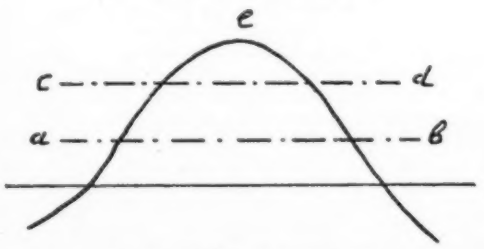


Fig. 11.—Effect of wave form.

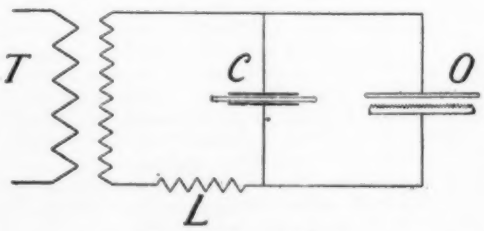


Fig. 12.—Connections.

Fig. 8.—Arc.

considered, but as none of them except one will answer our purpose we can be very brief about the others. It is of no use summing up all of the combinations; just a few may be enough to bring out the evidence clearly.

A positive plate and a negative sphere give no brush.
A positive plate and a negative wire give no brush.
A positive plate and a negative point give no brush.
A negative plate and a positive sphere give a brush.
A negative plate and a positive wire give a brush.
A negative plate and a positive point give a beautiful brush.

The reader will permit us for the sake of brevity not to dwell upon the fact that, of course, such terms as sphere and point require a more precise definition, but as the boundaries of discharges are just as vague as those of shapes, which after all differ only in degree of curvature, there is no need of further definitions and we trust on the reader's good will for understanding.

So much on the question of shape. Evidently there is no choice left. The best arrangement is to have the discharge from a pointed toward a flat surface, and if we make a drawing of the potential gradient that is likely to occur it will be clearly like the curve shown in Fig. 5.

It might be said here that the photograph of the true brush in Fig. 1 has been taken from one in free air from a small sphere against free air, no opposite pole being provided so as not to influence beforehand the free development of the brush.

In actual work one uses alternating current because direct current of very high tension (say 10,000 volts) is not so easily available as is alternating current. As it is only in the half-period in which the point is positive that it discharges a brush, the negative half-period is lost, not with respect to energy, but with respect to time.

There is a simple way to make up for this, shown in Fig. 9. Here each discharger proper is intended to emit the electric discharge from its sharp edged side when positive and to receive it on its flat back when negative (if we may express ourselves in a popular way). There evidently is no gain at all except in the reduction of the size of apparatus for a given capacity. The sharper the point the better it is; that means the less voltage it takes to have a discharge. In actual practice I used at first steel needles made especially to suit the purpose. But when I had to increase the capacity of the apparatus from two to twenty kilowatts it could not be done in that way on account of the high cost, as there were 100,000 needles per kilowatt. For this size of ozonator I used No. 35 pure nickel strips toothed like a saw (36 teeth per inch) and for the other electrode a nickel strip of suitable width, the width depending on the polar distance. In my case the width was ¾ inch., the polar distance being ½ inch. The size of the dischargers proper is of much greater influence than one might imagine at first thought. The flat surface should be ¼ more than the polar distance. The size of the positive sharp electrode matters little, but it should not be extremely short as it should be free from the influence of the electric field caused by its back.

There is a very convenient check to find out whether or not an ozonator has been designed properly. If it is properly designed the energy it takes is directly proportional to the total length of dischargers (or number of points). This statement will seem self-evident. However, those who have been working in this field know that at the beginning when the experimenter does not yet know all these details, he is every now and then surprised and very often puzzled as to the reason why after an apparatus has been built for say 100 watts, on making it twice as large it does not take twice as much energy. That will happen when the rules governing the brush discharge are overlooked, due to ignorance. I may say here that it has taken me over 12 years of experimental work and practice to bring the whole affair to a satisfactory end.

We will now describe an instance in which multiplication of discharging points does not correspond to an equal multiplication of wattage.

(2) *Spacing of Electrodes.*—The spacing apart of the different parallel dischargers proper is an interesting point of great importance. It bears on the principle of electrical shadow. An example will make clear what I mean.

In Fig. 10 *a*, *b*, *c*, *d*, *e* are the dischargers proper, mounted in such a way as to allow of easy displacement sideways when under test. One strip (*a*) will give a perfect series of brush discharges when connected up to the source of electricity, a 10,000-volt transformer. Now move a second strip near to its side. At a distance from the first strip of say anything above an inch it will work just as good as the first. The energy will be twice what it was before (case *c*). But when the second strip is moved nearer and nearer to the first one, the discharge is losing in brightness (*b*). Now let us move it away again till all is as bright as possible (*c*). Suppose this occurs at a distance of ¼ inch. Put in a third strip, make the distance again ¼ inch. Then the second discharger will be extinguished and only Nos. 1 and 3 will work (case *d*). Repeat this with a fourth discharger and so on and it will be seen that any but those at the end are extinguished. The inside dischargers will not discharge at all. The energy consumed is therefore not proportional to the number of strips, unless these are spaced apart so far that they do not longer interfere with each other's action (case *e*), that is until they are beyond each other's shadow. Since this spacing depends on the polar distance, at greater polar distance the brush spreads out wider and requires more spacing.

This experiment, which is very fascinating to watch, explains why multiplication of dischargers not necessarily means equivalent increase in capacity. It also makes clear the reason why from a flat surface one does not obtain any discharge from the central part, but only from the edges.

I may once more draw attention to the fact that we are speaking of discharges in free air without any solid dielectric being placed between the electrodes. If this is done, as we shall see later on, the conditions of working are altogether altered.

(3) *Material and Finish of Electrodes.*—It is quite immaterial of what material the electrodes are made. I tried nearly all the more easily available metals and never found the slightest difference. For the purpose of ozone making platinum would be the best, or gold, but, of course, these are out of question on account of excessive cost. Silver is rapidly corroded by ozone, and so are aluminium, brass, zinc, iron, but copper stands well and so does nickel.

But besides resistance to corrosion there is another property to be considered, viz., that of hardness. It is a very curious phenomenon that the perpetual bombardment of the negative electrode should result in an actual wear. After a year's use the flat nickel strip shows flaws, it has the appearance of a skidded rail (in miniature). But one would not expect wear on such a hard metal as nickel by bombardment of air molecules.

There is no wear whatever on the positive strip, so evidently the wear is not through metallic particles of the positive strip. This is important to note, for a wear of the positive electrode would indicate a change in the condition of working. Fortunately this does not happen.

The discharging positive electrode should be sharp-pointed, not sharp-edged. A razor blade gives very poor brushes. There must be real points because the brush must have a support for its stem. Perhaps it is better to say that the stem of the brush must have an inducement to build itself up, this inducement being provided by discontinuities in the line made either like teeth of a saw or as true points (needles).

The finish of the negative electrode should be smooth, without protruding parts or sharp edges or corners. These ought to be rounded off.

ELECTRIC AND MAGNETIC FIELD.

The influence of an electric field is very much disturbing and in large apparatus it may be very difficult to avoid it. We have already spoken of the disturbance caused by the electric shadow of the discharges, but here we have in view the stray fields caused by the metallic parts of the apparatus.

We have experienced great trouble from this cause and the most convenient way to avoid it was to have part of the apparatus built of wood instead of metal. These stray fields are uncontrollable and cannot be neutralized by proper grounding. By the way, it may be mentioned here that grounding a high-tension circuit is not such an easy thing as it looks. A magnetic field affects the brush discharge just as it would affect an ordinary alternating current. A strong field tends to "blow it out" and a tendency of sparking is set up.

As to the influence of electric radiation, such as ultra-violet light, this question has not yet been settled. Some people claim a very decided influence of ultra-violet light radiation on the working of brush discharges. I have never been able to detect any at all, but this may have been due to the powerful discharges which I had used.

CURRENT SUPPLY.

(1) *Source of Current Supply.*—For the study of the discharge, a statical machine is a very convenient source for the current but that is all. Any practical use is out of question for well known reasons. The use of Rhumkorff induction apparatus is the next step for an experimenter. The wattage that can be obtained is much higher than that from the former machine, but it is still of no practical use. Full credit may be given to the very interesting experiments one is able to make with it, but it can only be employed for research, not for actual use.

A high-tension direct-current machine, or direct-current on the Thury system has for a long time been my desideratum, but so far I have not been in a position to experiment with this kind of current. Alternating current has been my regular source of supply, the generator giving 110 volts, the transformer up to 60,000 volts for experimental work. Under practical working circumstances I have used 10,000 volts. (I may call attention here to the fact that at the time when I started my experiments, viz., in the year 1898, such high tensions were an absolute exception in my country, Holland, and the only possibility of using 60,000 volts was to build the transformer myself.)

(2) *Tension of Current Supply.*—There is an intimate connection between the width of the air gap and the tension of the current. It is easy to understand that the general formula will be $V = a + bl$ which means that in general the potential difference required to send the discharge through the air gap will be made up of a constant factor a and one depending on the width l of the gap. One may thus adapt either the polar distance of the dischargers according to the tension of the current, or one may regulate the voltage according to the given distance. When it comes to ozone making, however, and highest efficiency is sought after, there is no longer any such liberty in choice. Down to a certain limit, the best yield per kilowatt-hour, as well as the highest concentration (two quantities that are in opposition to each other), are obtained with the smallest possible air gap, called polar distance. This point has to be considered very carefully.

For the true brush discharge there is a lower permissible limit of polar distance. Under the most favorable conditions this lower limit is about ¼ inch for safe working, however, it is hardly possible to go below 3/8 inch, and as a rule we have worked our machines at ½ inch.

This settles the question of tension, which may be about 10,000 volts (a.c.). Of course, it should be as high as possible in order to get the highest current density and thereby maximum of wattage, the limit being set by the production of sparks between the discharges instead of the regular brush.

(3) *Frequency of Current.*—The danger of sparking can be very materially diminished by raising the frequency of the current to an extra high value. We have tried frequencies up to 600 periods per second instead of the usual 50 (100 in my country in 1898). The advantage of the possibility of using a higher frequency is counteracted by the fact that the output per kilowatt-hour is thereby reduced. When taking resource to high-frequency Tesla currents, there is hardly a possibility of the occurrence of sparks, but we have the drawback of an enormous decrease in output. These facts indicate advantages in the use of direct current for ozone making purposes. Perhaps somebody will take this up in future.

(4) *Wave Form.*—The wave form of the electromotive force is of theoretical, rather than practical importance. Still when we consider the question of wave form, it becomes clear why we can have a brush discharge without dielectrics.

Referring to Fig. 11, let the line *a b* represent the minimum voltage at which a discharge will occur. Then, if the top *c* represents the voltage at which sparking will take place, it is quite clear that if we know of a way to keep the actual voltage between the dischargers below that point *c*, say at the line *c d*, there will be no sparking, since the voltage is not high enough for the spark discharge, the polar distance being given. That is what is actually being done when we arrange a discharge to take place from sharp-pointed electrodes.

A spark discharge presupposes a certain amount of electrical charge. For just this reason it is not continuous but an intermittent, oscillatory discharge. The brush, however, is a steady flow and for this reason it does not give the electric charge an opportunity to accumulate for a spark; from a sharp point the electricity flows off so easily that there is no chance for a spark.

From this inference it should follow that a peaked curve would give more security against sparking than a flat one. In actual practice the deviation from the true sine wave is not so large as to make any difference for the brush discharge.

(5) *Safety Devices in the Current Supply.*—The discharge from either one point against a flat surface or from a series of points of any desired length against a flat strip all of suitable and harmonic design can be a true brush discharge and will remain so for any length of time *unless* there comes some disturbance either caused by a raise of tension or by a particle of dust or oxide that may cause a spark to be formed. Now a spark means a lowering of resistance of course at once followed by an increase in current density at that spot. This means raise of temperature causing again a decrease of resistance, etc. Evidently when a spark is once started it will not only remain but will increase. When we deal with an ozone apparatus of many hundred thousands of points it would not be possible to avoid all and every disturbance that might happen to come. But as it is of great advantage to have the apparatus work without any attendance at all, some safety device has to be applied, and this is what we will now briefly discuss.

Fig. 12 shows a special way of making the connections in the circuit from the secondary terminals of transformer *T* there is a self-induction *L* in series and a capacity *C* in shunt with the wires that lead to the ozonator *O* which represents a certain resistance. Through the combined effect of self-induction and capacity the secondary tension will be raised (Ferranti effect) to such an extent that, while the ratio of transformation of the transformer is 70, so that under ordinary circumstances the secondary tension would be 7,700, yet in this case it rises to 10,000, but not so unless there is a *certain* resistance at *O*. Suppose this resistance drops off say, on account of a spark, then the rise just mentioned from 7,700 to 10,000 volts will not take place. The voltage will be less. As soon as this is the case, the cause for the spark has also ceased or the possibility for its maintenance has vanished, the result being that any spark just about to start or already started, will, by its own being, make its continuity impossible It checks its own existence and it does this in a most beautiful and startling way with surprising accuracy. The raise of tension is the greater the more the product *L C* approaches unity. It can never be greater than under this condition. From a theoretical standpoint it is immaterial whether we obtain the raise of voltage through increase of *L* or increase of *C*, but when the load is heavy, i.e., the resistance is small, then one should rather increase *C* as an increase of *L* causes too much phase lag.

From the foregoing it will be understood that in the design of a large-sized ozonator every item has to be carefully calculated and the whole system has to be in perfect harmony. If this is so, there is no trouble, no attendance is required. When the apparatus has once been adjusted to the point of best working, the occasional sparks are taken care of by themselves (some little sparking does not interfere with the proper working and is hardly to be avoided on account of particles of rust on the electrodes). The principal advantage lies in the fact that with this arrangement the arc discharge is an *absolute impossibility* (even when the tension is raised 20 per cent purposely, to demonstrate this fact.) It should be borne in mind that in this arrangement there is no spark gap, as in the Tesla method, which would cause high-frequency discharge. Perfect and most strikingly beautiful brush discharges can be obtained in this way, and in an absolutely reliable working condition.

As explained, this way of making the connections has to be considered as a safety device. The discharge itself is not altered at all. It may be just as good when the usual connections are employed. This brings us to the second part.

PART II.—THE BRUSH DISCHARGE WITH THE USE OF A SOLID DIELECTRIC.

As a result of the desire of having some safeguard against the dangerous arc discharge, several devices have been invented and applied. Since the days of the first laboratory ozonator the principle of placing a solid dielectric between the electrodes has been applied by numberless "patentees." We shall deal with this at greater length and, therefore, will first mention other systems.

The drawback of the use of glass is its liability to crack and that is why many have endeavored to do without it. It was in 1894 that Schneller announced that he was able to obtain the brush discharge without making use of any solid dielectric. This was at first considered to be an impossibility, but Schneller proved the soundness of his assertion by constructing a 2-kilowatt apparatus which did the work, to everybody's surprise. Schneller inserted a "high resistance" in the high-tension circuit, said resistance to be of the order of 20,000,000 ohms and made of a glass tube filled with 80 per cent glycerine. The principle, though interpreted in an altogether wrong way, had the merit of being quite new and Schneller's experiments were pioneer work. For his 2-kilowatt apparatus he used seventy-five of these glycerine-filled tubes of 20,000,000 ohms each, in parallel with his 50,000-volt circuit. The discharge he obtained was a beautiful sight, but viewed from the commercial standpoint the system proved to be a failure because of its extremely low efficiency. From the scientific standpoint it is interesting to point out that said "resistance

tubes" do not work as ohmic resistance, but as a pseudo capacity. It is easy to demonstrate that an ohmic resistance does not do the work but, on the contrary, provokes arcing instead of preventing it. This fact is quite in accordance to the theory of the discharge.

A few years later Schneller took out a patent for the use of enamel as dielectric, but had the shrewdness not to call it such. He said it was used for having a more equal and smooth surface of electrode!

The next thing that came out was the use of high frequency for the purpose of ozone making. Now it happens that the unsurpassed beauty of the Tesla dark discharges has no bearing on their efficiency and that killed the system. It is true that with this system there is no danger at all from arcing, but as after all the object is ozone manufacture rather than display of beauty the system has never entered the market.

Another device was that of Otto, who tried the use of revolving electrodes in order to either prevent arcing or when arcs were formed to extinguish them by drawing them out. The system never did any good because arcing should not be *corrected* but *prevented*. Arcing causes nitrous compounds to be formed and causes great damage to the apparatus

After having been experimenting with all known systems and after studying them carefully, I came to the conclusion that in order to obtain the brush discharge and nothing but this particular one, it is not necessary either to use solid dielectrics between electrodes, or a high resistance in series, or a high-frequency current, or revolving electrodes. All that is really necessary is a thorough knowledge of the subject and according to that, we should endeavor to realize in actual practice what theory indicates as advisable. This has led me to my system and the fact that I admit frankly that my system has not any more *raison d'être* on account of its low efficiency will make it clear to the reader that it is not as a rival or competitor that I now classify all systems as dead ones, except one which is based on the use of a solid dielectric.

The reason why I have been dwelling so long on those others is just to point out the *importance* of the latter one and to prove that its survival is not a mere chance or commercial attainment but the logical outcome of merit.

In order to fully appreciate the glass-dielectric ozone apparatus, it was necessary to learn by experience that it is the best we have at present and probably for the near future.

When using a solid dielectric there is no chance for a spark nor for an arc to set up. The discharge is always right, whatever the arrangement, and there is but one difficulty left, viz., that of failure of the glass. Many failures on this account are due to overloading. Too much energy on a given surface causes too much heating up and this will always result in a breakdown, sooner or later, but usually sooner. The perpetual heavy dielectric strain on the glass also causes occasionally or perhaps always, a change in the nature of the glass, which as is well known is very far from being a body in molecular equilibrium. Dielectric hysteresis is another source of heat and danger. The success of a glass ozonator, evidently, depends therefore, for the greater part on the quality of the glass. This is a physical and a chemical problem rather than a technical one for the present. The technical side of the glass ozonator is no problem at all for those who are familiar with the business. The failure of so many "systems" is the logical result of ignorance.

The second great advantage of glass-dielectric ozonators is that they allow of a very small polar distance of dischargers, and that means high concentration as well as high output if the current density is great, the difference in yield being up to ten times as much. This puts all the other systems out of service. Thus it happened that after twelve years of elaborate experimental and practical research, I finally had to give up my system for a better one, the original glass dielectric system. But facts are facts and science takes no notice of personal pride and ambitions.

There are numerous patents for ozonators. Some people prefer glass plates to glass cylinders, others do the reverse. Some believe in the beneficial effect of cooling the air, others do not. Some people think much of complicated arrangements, other believe more in simplicity. There are, however, some details of interest, but as we intend to discuss ozonators on another occasion, we shall not refer to these here. If the dielectric system has so many advantages and but one disadvantage, namely the treacherous character of glass, why not use any of the many other solid dielectrics? That is a question likely to be put forward. It is because no other dielectric will do.

Ozone being such a powerful oxidizing agent, is detrimental to most dielectrics of organic base. Rubber, for instance, is destroyed in a few seconds. So none of that group can be used. Moreover, the material in question has to possess certain mechanical properties and has to have a certain thickness. For this reason shellac or other varnishes cannot be used as they cannot be had in sufficient thickness. The whole group of those conglomerates lack homogeneity and for that reason cannot be used. Others, again, like fiber, asbestos, paper, etc., are too porous for electricity, which "eats" its way through. Then come some minerals. Most of them are not to be had in convenient shape. Slate is also porous. Mica will answer the purpose but poorly, as it cannot bear very well the heating up; its lamellation is a further disadvantage, the layers becoming more and more separated from one another until finally it is not one thickness but several. Micanite is no better. Bakelite did not exist at the time when I tried every one of the dielectrics, so I do not know its behavior.

Of the fused materials there are enamel, porcelain, and vitrified silica. The first can never be applied faultlessly on a surface, and even if it could it would be no good, its dielectric strength being too low and its thickness too small.

Porcelain fails through lack of homogeneity. So does, for the present, the vitrified silica; it is very fragile and its fusion has not been quite so complete as to remove all flaws, air bubbles etc. It may be however that it will play an important rôle in ozonators in future because its quality is rapidly improving every year. So it is that only glass combines all the requirements of dielectric strength, mechanical strength, chemical strength and variety of shape and thickness.

One more point of scientific interest is the fact that the dielectric strength of ozone is much higher than that of air. If one leaves the ozone in the apparatus so as to get an increasing concentration the tension of the current has to be raised continuously in order to keep the wattage constant. This circumstance puts a limit to the maximum concentration of ozone obtainable; it may be in the neighborhood of 30 grams per cubic meter.

A fact generally overlooked is that a large load of ozonators brings a considerable amount of capacity into the circuit which should be checked by self-inductance.

Stationary Oil Engines*

The Manufacture of Small Sizes

DURING the past year or two so much has been said and written regarding the oil engine for marine work that it is sometimes apt to be forgotten, except by those immediately interested in the subject, that enormous strides have been made in the development of the oil engine for stationary purposes. Possibly the reason is that the problem they present is not such a fascinating one as that relating to the propulsion of ships, but from a business point of view it is perhaps even more important. At any rate, judging from the results which have recently been obtained by those firms engaged in the construction of stationary oil engines, the profits to be derived from their manufacture are in excess of those obtained from the building of marine oil engines. Admittedly the latter involve more difficulties, and though in the future their manufacture may become a very remunerative business, even so it may possibly not be more important than the building of oil engines for land purposes.

SEMI-DIESEL ENGINES.

It is particularly with motors of the smaller sizes that progress has been made, and apart from the question of Diesel engines there is an enormous business in the construction of engines up to 50 horse-power or 60 horse-power. The great demand for small engines has arisen mainly in the last three or four years. It is probable that had the price of gasoline remained at a lower figure the gasoline engine would have been widely adopted for stationary work, and as things are it is frequently used; but the number made for such purposes is small when compared with the heavy oil engine and the paraffin motor. Even the latter has suffered considerably from the cost of fuel, and taking the matter in its general aspect and omitting special cases, it is evident that the future lies almost entirely with the heavy oil engine, mainly of the so-called semi-Diesel type, for powers at any rate up to 60 or 100 horse-power.

Semi-Diesel engines, although differing in certain constructional details, according to the manufacturer, are all essentially of the same type and are generally made to work on the two-cycle single-acting principle. The four-cycle motor has made some headway in certain quarters, but in numbers at any rate it is surpassed by the two-cycle engine. There is no doubt that the stationary motor is easier to build than the marine engine from the point of view that it receives better attention as a rule. Moreover, the question of reversibility does not arise, while all the conditions of its operation are generally much more satisfactory than in the case of the marine engine.

The motors are made of both the vertical and the horizontal type, according to the design favored by the particular firm constructing them, and neither possesses any features that render it markedly superior to the other. The question of floor space is not usually important with these relatively small motors, so that from this point of view the horizontal motor is not at its usual disadvantage. Again, these motors never stand very high, so that the general advantage claimed for the horizontal motor that it is more accessible than the vertical does not amount to much in the case of semi-Diesel engines of relatively small power. There is not, therefore, a great deal to be said on one side or the other, although it is evident that if a firm should wish to manufacture this kind of motor for both land and marine purposes it would be advisable to standardize on the vertical type.

Here it may be pointed out that in regard to standardization the semi-Diesel engine shows itself wonderfully suitable for manufacture on an extensive scale. The number of parts in it is not large, so that even though every one be standardized, no very great complication in works management is introduced, while the cost of production is much diminished. Most of the firms make large numbers of engines for stock, but it must be admitted that by the time they are built they are usually sold, although intended as stock when their construction was begun.

SIMPLICITY AND ADVANTAGES.

It is not surprising that the majority of these motors are constructed for service abroad, and it can readily be understood that a prime mover which can easily be erected at any spot most convenient for its work, and which requires practically no other appurtenances than an oil tank, can render itself invaluable in many industries and for an enormous number of diverse purposes. The simplicity of the motor, again, appeals to the purchaser, since he can leave it in the hands of an unskilled native with a reasonable prospect of success, and as a matter of fact, provided these engines are not interfered with, they can generally be relied upon to give very satisfactory service without much attention. With the entire absence of valves the number of working parts is so small that little can go wrong with it provided it is not tampered with. The Diesel engine has the disadvantage of a large number of valves in comparison with the semi-Diesel engine, but it is more efficient and burns a rather cheaper grade of fuel. As regards this question of fuel it may be mentioned that semi-Diesel engines, as a rule, consume about 0.6 pound of oil per brake horse-power hour, and the fuel most commonly employed is gas oil, although, of course, various kinds are used according to the locality in which the engine is erected and the fuel which is available in the district. From experiments which have been carried out it appears that the engines can be made to run successfully on very much heavier oil than gas oil, and in fact some are stated to be suitable for any fuel which has a specific gravity not greater than unity, though this seems a somewhat optimistic estimate.

Speaking generally, it can hardly be said that such motors, at any rate for land purposes, come into competition with Diesel engines, since the powers in which they are mostly constructed are scarcely high enough to be suitable for Diesel engines under the best conditions. For small powers, Diesel engines are relatively very expensive, and from this point of view alone the semi-Diesel engine has a great advantage. Its main disadvantages lie in the fact that the hot-bulb has to be heated up before starting, an operation which may take anything from 10 to 20 minutes, while the fuel costs for running are slightly in excess of those of the Diesel engine. Against this have to be put initial cheapness and general simplicity of operation, so that even where competition is likely to occur and does occur between Diesel and semi-Diesel engines it is not difficult for the manufacturers of the latter type of motor to put forward reasons which point to the fact that their engine is a better one for the purposes desired.

In considering this problem of the development of oil engines for stationary purposes it is interesting to notice that although so much work has been done in Germany in connection with the Diesel engine, and that country is probably to the fore in the design and manufacture of this type of motor, its position in the manufacturing world as regards the semi-Diesel engine is far inferior to that of this country. It might seem that builders in Germany have not much faith in the semi-Diesel engine, but probably the reason is that so much attention has been paid to the Diesel motor that the smaller engine has been somewhat overlooked by manufacturers, who have not realized the great possibilities in front of it.

*Reproduced from the Engineering Supplement of the *London Times*.

The Law of Population Concentration*

By Prof. Felix Auerbach

An important characteristic which we study in population statistics is the density of the population; that is to say, the number of inhabitants per square mile. But it would be a mistake to suppose that a knowledge of this characteristic tells us all that we need to know about the distribution of the population. Another characteristic has been named by me the *concentration* of the population. This term is reserved to describe not merely the density of the population, but its massing together at certain points, with a compensating comparative scarcity at other points. The question arises how we can measure this concentration. I have succeeded not only in obtaining such a measure, but in discovering in this way a very remarkable relation.

Suppose we arrange the cities of a given country, for instance Germany, in order of their population (1910), and give each a number representing its place in the list. Let us then multiply the number attached to each city with the number of its population. Omitting unnecessary zeros and rounding off the last figure, we obtained the following very remarkable table.

TABLE OF GERMAN CITIES.

Number in Order of Magnitude, N_1.	City.	Number of Inhabitants (Thousands), N_2.	Product, N_1 N_2
1	Berlin	3,579	36
5	Cologne	593	30
9	Frankfurt	449	40
15	Chemnitz	306	46
20	Stettin	258	52
25	Strasburg	191	48
30	Posen	157	47
35	Brunswick	144	50
40	Kattowitz	128	51
45	Zwickau	118	53
50	Hamborn	103	52
55	Oberhausen	90	50
60	Görlitz	86	52
65	Wilhelmshaven	78	51
70	Pforzheim	69	48
75	Harburg	67	51
80	Koblenz	65	52
85	Mors	60	51
90	Brandenburg	54	49

TABLE OF AMERICAN CITIES.

Number in Order of Magnitude, N_1.	City.	Number of Inhabitants (Thousands), N_2.	Product, N_1 N_2
1	New York	4,767	48
2	Chicago	2,185	44
3	Philadelphia	1,549	47
4	St. Louis	687	27
5	Boston	671	34
6	Cleveland, Ohio	561	34
7	Baltimore	558	39
8	Pittsburgh	534	43
9	Detroit, Mich.	466	42
10	Buffalo	423	42
20	Kansas City	248	50
30	Toledo, O.	168	50
40	Paterson	126	50
50	Albany	100	50
60	Springfield, Mass.	89	53
70	St. Joseph, Mo.	77	54
80	Evansville, Md.	69	55
90	Charleston, S. C.	59	53
100	South Bend, Ind.	54	54

If we neglect the first two items in the table of German cities it will be seen that the products in the last column vary but slightly from an approximate value of about 48. Similar remarks apply to the table of American cities, except that the constant here is somewhat higher, we have therefore the law.

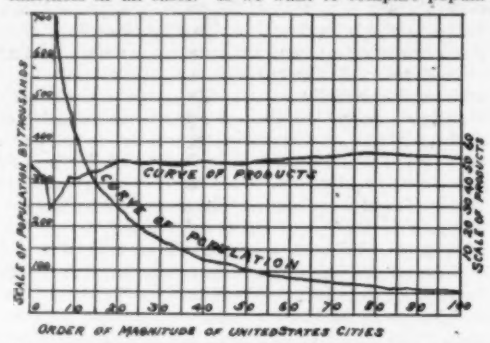
The population of a city is inversely proportional to the number indicating its rank among the cities of a given country. Or—

The product of the "rank" of a city into its population is (nearly) constant for a given country.

*Abridged from *Die Umschau* for the Scientific American Supplement. The author's original publication in detail appeared in the February issue of *Petermann's Mitteilungen*.

We may use this product to measure the population concentration of the given country. In the case of Germany it is about 48.

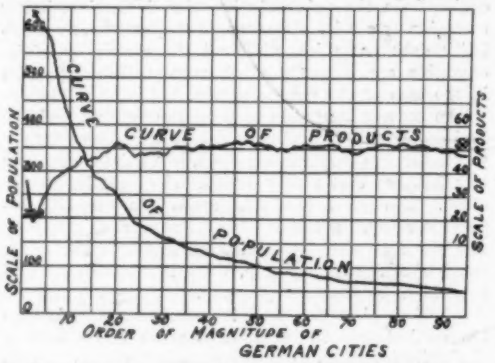
I have extended my investigations to many other States, and have found the law to hold with great exactness in all cases. If we want to compare population concentrations of different countries, we must allow for the differences in their total population. To do this we divide the product obtained above by the total population of the country in question. We obtain in this way the following numbers for the specific concentration:


SCALE OF POPULATION BY THOUSANDS
CURVE OF PRODUCTS
CURVE OF POPULATION
SCALE OF PRODUCTS
ORDER OF MAGNITUDE OF UNITED STATES CITIES

	Absolute Concentration.	Specific Concentration.
Holland	5.3	91
Great Britain	39.4	87
Belgium	5.8	82
Switzerland	2.6	75
Germany	47.8	74
United States of America	53.0	57
Italy	15.9	47
France	17.4	44
Spain	8.6	43
Austria-Hungary	16.8	32
Russia in Europe	24.2	19
British India	36.0	11

These figures suggest many interesting reflections. Thus for example, the population density is only about twice as great in Great Britain as in India, while the concentration is more than eight times as great: This means that in India only a small proportion of the population lives in the cities, where the population is dense.

It is also interesting to observe the changes in the absolute and specific concentration of the population



in Germany, for example, over a period of time extending from 1895 to 1910. The following are the figures obtained:

	1895.	1900.	1905.	1910
Absolute Concentration	28.7	34.2	42.2	49.5
Specific Concentration...	55.	61.	70.	77.

It will be seen that the actual concentration has increased by 72 per cent, the specific concentration only by 40 per cent in the period of time indicated.

The law which has here been exposed was discovered by purely empirical observation. The problem remains to determine the causes which lie at the bottom of the phenomenon observed. But on this point there is at present no definite information available.

Difficulties of Silencing in Aeroplane Construction

By Pegasus

So far as present information and prospects go, there is no perceptible sign of a truly silent aeroplane being produced. The newest designs of one of the most popular of aeroplane motors entirely exclude the silencer. As is well known, this Gnome engine will take in the air for combustion by the exhaust valve, and then a rich mixture will be injected into the cylinder through a port in the side uncovered by the piston. With this disposition the use of a silencing chamber which could retain any part of the exhaust gases is impracticable, so far as one can see at present.

The silence of the propeller is another matter which is apparently receiving no study. Certain it is that the low roar of the air caused either by vibration of the blades or by intermittent eddies leaving the blades is a remarkably far-reaching sound. It may be that the use of multi-blade propellers, or of metal-bladed propellers such as seaplane work is evidently calling for, may by a happy chance help us over the difficulty but it is very doubtful. When it is realized that in spite of long experience the silencing of epicyclic gear wheels is still a mystery, the difficulty of propeller silencing may be better apprehended. In addition, the tappets and valve gears of aeroplane engines are usually extremely noisy, and the wind hums loudly in the wires and past the struts and skids and wheels, so that all known aeroplanes are still a pandemonium of noise.

There is no aeroplane in current use to-day in which a five minutes' conversation can be maintained through the free air between pilot and passenger, while in most machines communication by yelling and signaling is still the only means possible. The engine silencer itself is not very popular with flyers, and when it has been fitted it has soon been removed, partly for the sake of the extra fraction of power thus gained, and partly because the loud assurance that the engine is not misfiring in any cylinder is desired. War conditions would alter this without doubt, not because the sound on the earth from 3,000 feet is important, but because the occasional necessity for descents to lower levels and rising therefrom unperceived would assuredly assert itself.—*London Times.*

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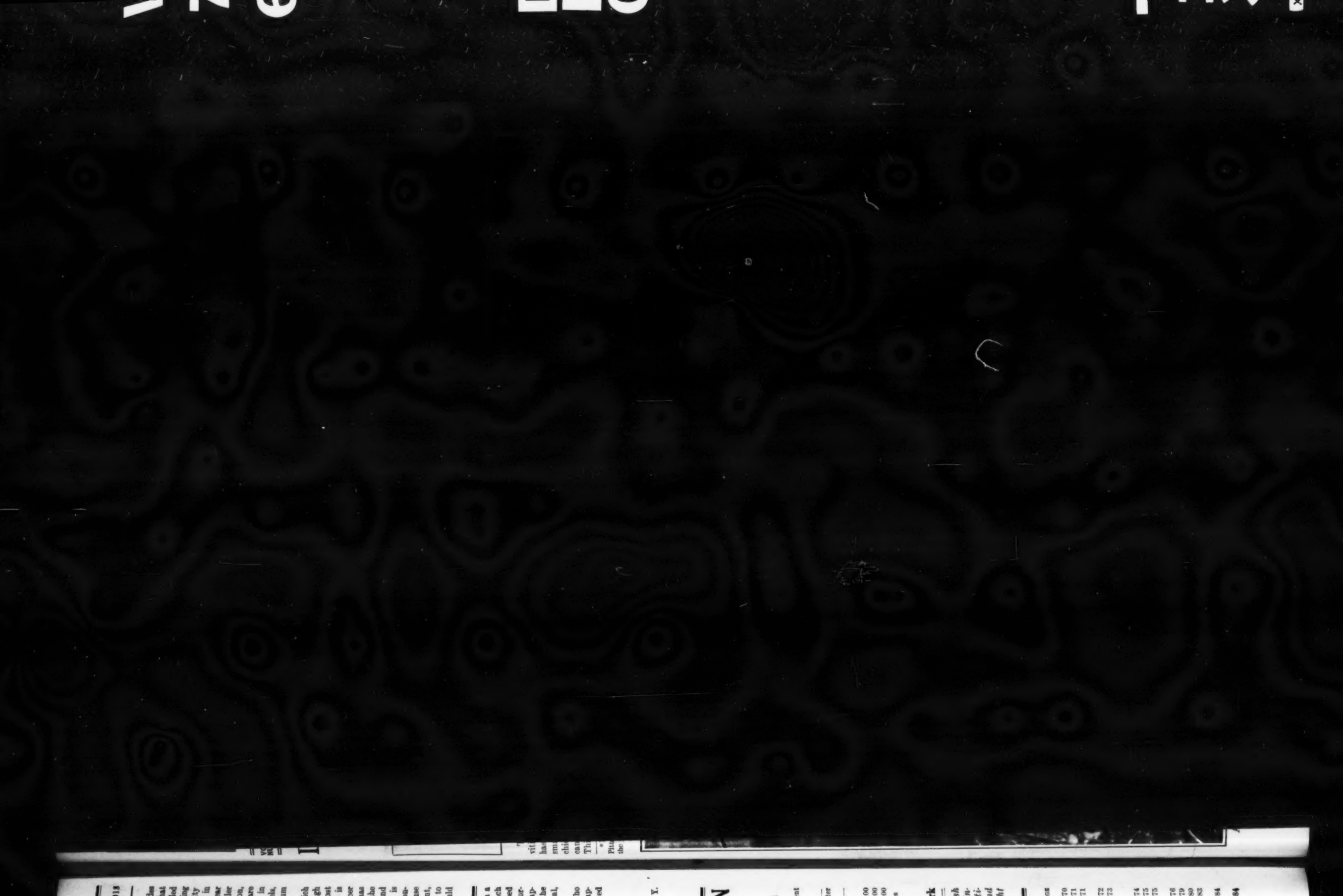
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